NOVEMBER 1955

THE WELDING JOURNAL

IN THIS ISSUE

Pressure Welding of Continuous Welded Rail 1065

Lower Part Cost by Projection Welding 1070

Gamma Radiographic Control of Welded Transmission Lines 1081

Seam Welding of Low Carbon Steel 529-s

Lithium Additions to Brazing Alloys 535-s

Weld-Metal Cracking in High-Strength Steel 544-s

Temper Brittleness of 1Cr-$^{1}/_{2}$Mo Weld Metal 553-s

Fusion Welding of 24S-T3 Aluminum Alloy 558-s

Experiments on Brittle Fracture of Steel Plates 570-s

Table of Contents 1061

Editorial 1063

Index to Advertisers 1152

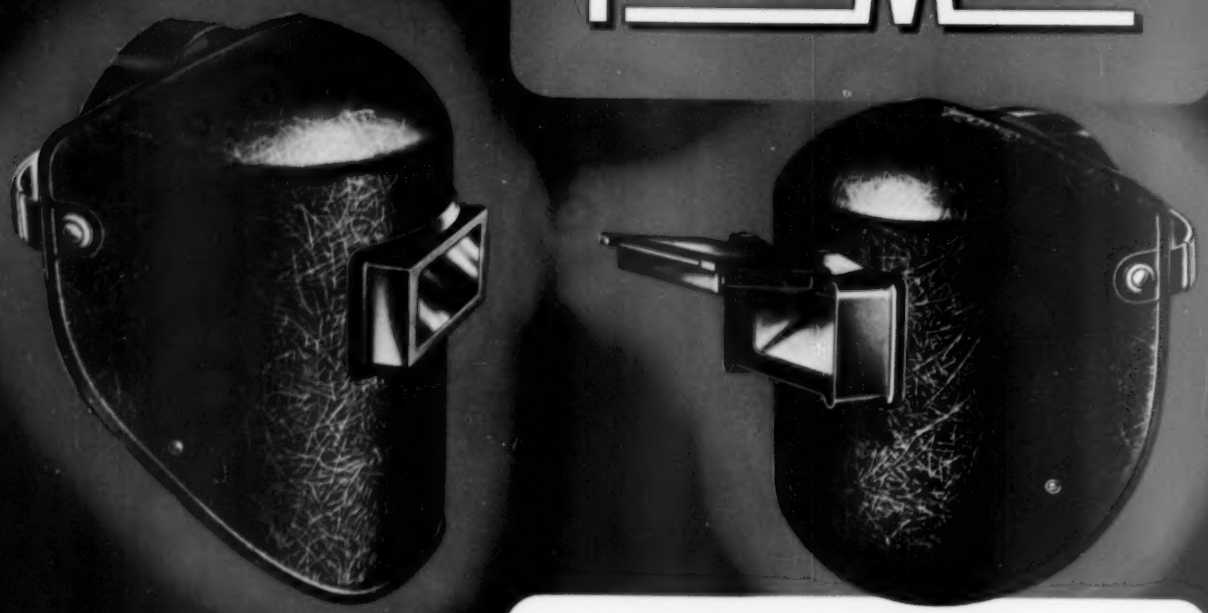
OFFICIAL PUBLICATION OF THE AMERICAN WELDING SOCIETY

Engineered BEST . . . and PROVED

BEST by WORK TEST!

50 YEARS of QUALITY and PROTECTION by

FIBRE-METAL



THE WORLD'S LARGEST MANUFACTURER OF SUPERIOR PROTECTIVE EQUIPMENT

PREFERRED by Welders *year after year!* And here's WHY: Highest *quality, comfort and dependability!* Built-in features found in no other Helmets: Wide Range Headsize Adjustment, 4-Position Helmet Stop, Special Friction Joints to hold *any* helmet position. All glass holders inside insulated. Fibre-Metal was *first* with seamless, compression-molded shells . . . with beaded edges . . . for strength and safety. *First with Fiberglas.* Keep ahead with Fibre-Metal Products . . . sold the world over by all leading distributors and dealers. *Ask for Bulletin No. 39.*

THE FIBRE-METAL PRODUCTS COMPANY
CHESTER, PENNSYLVANIA

FIBRE and FIBERGLAS HELMETS

Here's Why

200 to 600 amp. Electric Drives

. . . you get better welding faster with

HOBART arc welders

Check these "extra quality" exclusive features that CUT WELDING COSTS!

1. All arc welded steel frame
2. Convenient cable connectors
3. Outside wheel gives 10 steps of welding ranges
4. Inside dial gives 100 steps of welding ranges (by adjusting both wheel and dial you can get 1000 volt-amp. combinations)
5. Bi-directional ammeter
6. Bi-directional voltmeter
7. Convenient start and stop buttons
8. Ground cable connector
9. Drip-proof steel cover—easily removed
10. Optional equipment: Choice of portable mountings—meters

Top performance and low cost are Hobart bywords that mean you get extra years of dependable service with low maintenance cost—at NO extra charge.

Hobart's liberal use of copper, two-way ventilation, greater arc stability, safer, more efficient operating temperatures, make Hobart today's best welder value.

Choose a Hobart—you'll find it's the one welder that gives you superior performance with day-in, day-out economy of operation. Write today for full information on the welder of your choice!

Hobart Brothers Co., Box WJ-115, Troy, O., Ph. 21223.

200 to 600 amp. Gas Drives

AC Transformer

200 amp. "Husky Boy"

200 amp. AC-AC

You'll like these smooth welding Hobart electrodes

A simple comparison will prove Hobart's superior, top quality welding—in every application. You'll be surprised at the real difference in Welding Electrodes. Get the extra speed that means lower production costs—Try Hobart.

HOBART BROTHERS CO., BOX WJ-115, TROY, OHIO, PHONE 21223

Without obligation, please send me complete information on items checked:

☐ _____ ampere
☐ Electric Drive ☐ Gas Drive
☐ Transformer ☐ "Husky Boy" ☐ 200 amp. AC-AC

Our work is _____

NAME _____

POSITION _____

FIRM _____

ADDRESS _____

CITY _____ STATE _____

It all adds up!

Arc and Thermit welders for years have looked to Metal & Thermit for the electrodes, machines, and accessories they need, and for the research, engineering data, technical assistance, and ordering convenience that Metal & Thermit can offer. To the thousands of welders specifying M&T equipment, it all adds up to profitable welding. You, too, can enjoy the same unsurpassed purchasing economy and technical assistance by which so many others profit. Write now or call your M&T man for information on your requirements. There's one near you.

M&T welding products include:

MUREX ELECTRODES for

mild steel — aluminum bronze
low alloy steel — cast iron
stainless steel — aluminum
hard surfacing

M&T WELDING MACHINES

A.C. transformers — D.C. motor generators
D.C. rectifiers — D.C. engine driven
Inert arc

M&T WELDING ACCESSORIES

holders — helmets
cleaning tools — lugs
cable — gloves
ground clamps

THERMIT WELDING MATERIALS and ACCESSORIES

for the fast, low-cost fabrication and repair of heavy equipment.

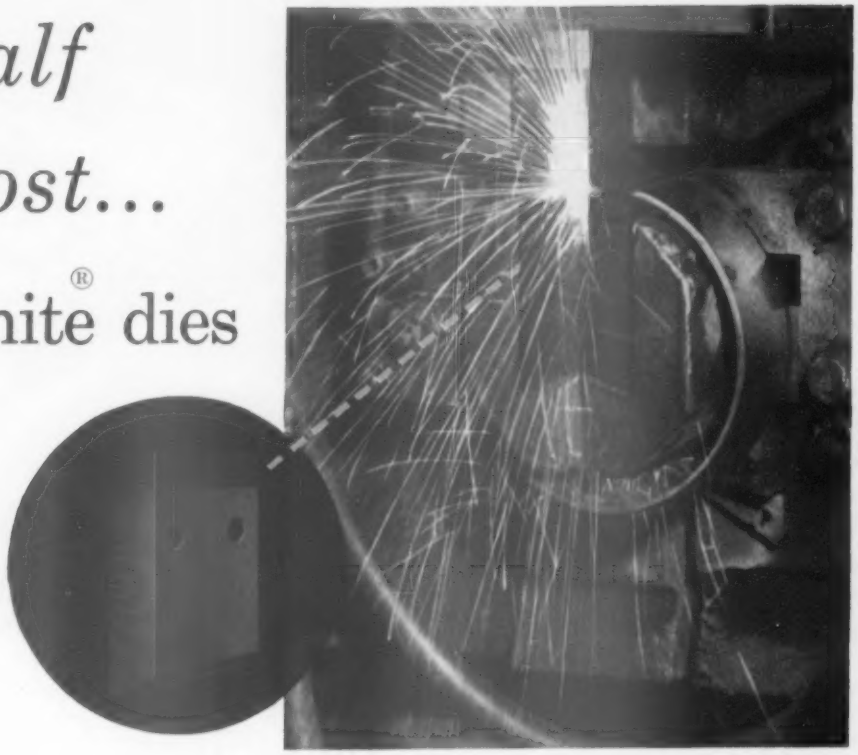
METAL & THERMIT CORPORATION

Welding Division

100 EAST 42nd STREET, NEW YORK 17, N. Y.

4 times more welds ...at half the cost...

with Elkonite® dies



Die insert for this flash and butt welding machine is faced with Elkonite 10W53 . . . a dense, hard material with high resistance to arc erosion, high strength and good electrical conductivity. The backing material is Mallory 53 alloy.

On the flash butt welding of transmission brake bands, a large manufacturer of automatic transmissions has made real improvements in the economy and volume of production . . . by the use of Mallory engineered die inserts faced with Elkonite alloy. Here are the actual production results:

Electrode life quadrupled. Elkonite-faced inserts produce over 32,000 welds . . . in contrast to 8000 with the previous type of dies.

Down time reduced 75%. Longer runs between dressing cut machine down time . . . helps in maintaining high production rates.

Lower cost per weld. Cost of die insert material per weld is *less than half* what it used to be.

You can find a cost-saving, production-boosting solution to your own resistance welding problems by calling on Mallory. An unequalled variety of electrodes in scores of shapes and sizes are available . . . with the exclusive Mallory fluted cooling hole or standard round hole. You can count on Mallory, too, for electrode holders, seam welding wheels, castings, forgings and dies. The selection of standard designs covers most of the welding work you will encounter. For special requirements, your nearby Mallory welding distributor will be glad to aid in your selection . . . or our staff of welding specialists will give your problem the benefit of our years of experience in the welding field.

For the latest technical data on the Mallory line, write to us for a copy of the Mallory Resistance Welding Catalog.

Expect more . . . Get more from

P. R. MALLORY & CO. Inc.

MALLORY

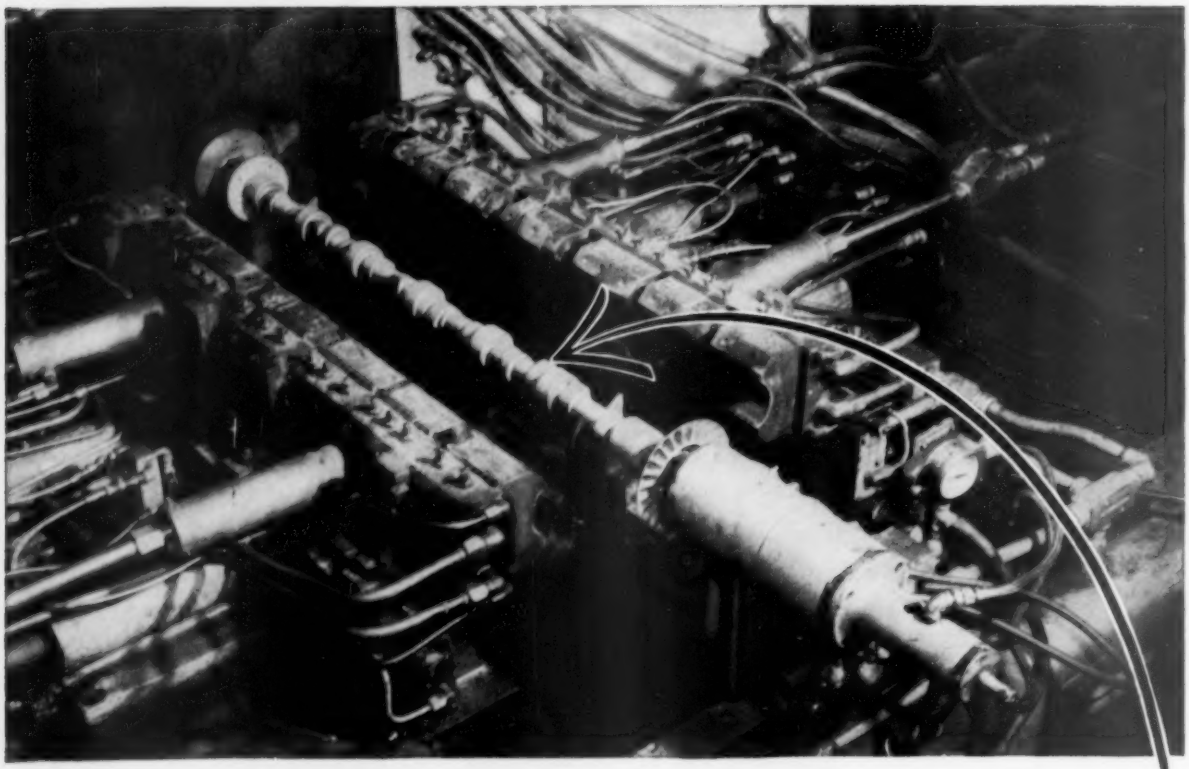
P. R. MALLORY & CO., Inc. INDIANAPOLIS 6, INDIANA

In Canada, made and sold by Johnson Matthey and Mallory, Ltd., 110 Industry Street, Toronto 15, Ontario

Serving Industry with These Products:

Electromechanical—Resistors • Switches • Television Tuners • Vibrators
Electrochemical—Capacitors • Rectifiers • Mercury Batteries
Metallurgical—Contacts • Special Metals and Ceramics • Welding Materials

For information on titanium developments, contact Mallory-Sharon Titanium Corp., Niles, Ohio



Automatic Flame-Hardening Boosts Production 300%

A cross-section view of this camshaft shows an even, uniform depth of the hardened surface.

Using an automatic oxy-acetylene flame-hardening machine, a leading manufacturer of trucks and marine equipment increased the production of flame-hardened gears, bearings, and camshafts 300 per cent. Parts are flame-hardened on as many as 22 different surfaces in fast, simple operations.

The flame-hardening process produces wear-resistant surfaces on large and small sections without heating the entire part . . . Distortion is at a minimum, and case depth is easily and accurately controlled. Flame-hardening is fast and relatively simple compared with other methods of hardening metal such as nitriding and carburizing. Low cost, portable flame-hardening equipment is available for the majority of applications.

Your local LINDE representative will be glad to show you how to produce machine parts with a tough, ductile interior and a hard, wear-resistant surface. Start saving now, call him for more information on flame-hardening.

LINDE AIR PRODUCTS COMPANY
A Division of Union Carbide and Carbon Corporation
30 East 42nd Street UCC New York 17, N. Y.
Offices in Other Principal Cities
In Canada: LINDE AIR PRODUCTS COMPANY
Division of Union Carbide Canada Limited, Toronto
(formerly Dominion Oxygen Company)

Linde
Trade-Mark

"Linde" is a registered trade-mark of Union Carbide and Carbon Corporation.

THE WELDING JOURNAL

VOLUME 34 • NUMBER 11 • NOVEMBER 1955

TECHNICAL PAPERS, ITEMS AND REPORTS

Editorial—Welding the Challenges of Tomorrow, by Monro B. Lanier 1063

An Application of Pressure Welding to Fabricate Continuous Welded Rail, by David C. Hastings 1065

Lower Part Cost by Projection Welding, by C. H. Burgston 1070

The Gamma Radiographic Control of Welded Transmission Lines, by C. C. Bates 1081

Editorial Previews—Linde Unveils Inert-Gas Tungsten-Arc Cutting of Aluminum 1097

PRACTICAL WELDER AND DESIGNER

Tunnel Linings Produced on Production-Line Basis 1099

Welding Cross-Bearers for Steel Railroad Cars, by R. C. McMillan 1100

Motorized Chair Gives Invalids a Lift, by R. L. Fuller 1101

Aluminum Window Frames Fabricated by Inert-Gas Tungsten-Arc Welding, by W. J. Hance 1102

Distortion Cut in Welding of Giant I-Beams 1103

SOCIETY AND RELATED EVENTS

Society News 1104

Employment Service Bulletin 1106

Section News and Events 1107

New Members 1122

Abstracts of Current Patents 1126

Current Welding Literature 1127

Personnel 1130

News of the Industry 1136

New Literature 1144

New Products 1146

Index to Advertisers 1152

WELDING RESEARCH SUPPLEMENT

Seam Welding Dissimilar Thicknesses of Low Carbon Steel, by M. L. Begeman and E. J. Funk 529-s

Lithium Additions to Brazing Alloys, by N. Bredzs and D. Canonico 535-s

Investigation of Weld-Metal Cracking in High-Strength Steel, by R. P. Sopher, A. J. Jacobs and P. J. Rieppel 544-s

Temper Brittleness of 1CR-1/2Mo Weld Metal, by W. J. Lester and G. R. Prescott 553-s

"Fish Eyes" in Low-Hydrogen Weld Metal, by K. L. Zeyen 557-s

Fusion Welding of 24S-T3 Aluminum Alloy, by J. B. Arthur 558-s

Experiments on Brittle Fracture of Steel Plates, by D. K. Felbeck and E. Orowan 570-s

Effects of Residual Stresses in Welded Structures, Discussion by A. W. Huber and L. S. Beedle 575-s

Published for the advancement of the science and art of welding by the American Welding Society

Published monthly by the American Welding Society. Publication office, 20th and Northampton Streets, Easton, Pa. Editorial and general offices, 33 West 39th St., New York 18, N. Y. Subscriptions $7.00 per year in the United States and possessions; foreign countries $8.50. Single copies, nonmembers $1.00; members 75 cents. Entered as second-class matter January 5, 1932, at the Post Office at Easton, Pa., under the act of March 3, 1879. Copyright 1955, by the American Welding Society. The Society is not responsible for any statement made or opinion expressed in its publications. Permission is given to reprint any article after its date of publication provided credit is given.

1. High climb to tack weld top course of a sulfate digester in position. Chicago Bridge & Iron Company makes the parts shown of 10% Inconel-clad steel under the trade name HORTONCLAD®. Its Inconel (a nickel-chromium alloy) surface withstands corrosion by pulping liquor at 340-360°F. and under 125 psi pressure. The welds do, too. That's because . . .

2. Inconel-clad side is welded first with "142" 80/20 Nickel-Chromium Electrodes. This minimizes iron dilution in the welds. The resulting weld metal matches the Inconel cladding in corrosion resistance. So — for lower costs — after the first bead the welder switches to "132" Inconel Electrodes. This electrode is produced for welding Inconel to itself, but can be used in this application since the "142" deposit provides proper control of iron dilution. So . . .

Look At This Big Pulp Digester To See How...

Inco "142" and "132" Electrodes Simplify Welding Inconel-Clad Vessels

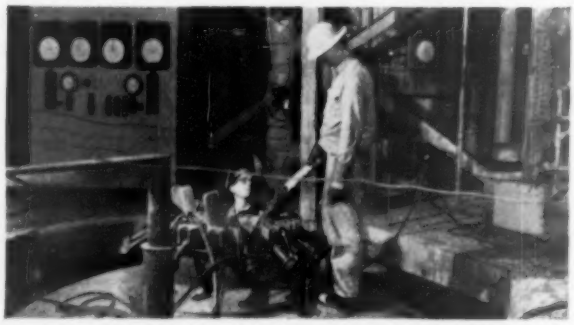
When *you* weld Inconel-Clad Steel, use "142" 80/20 Nickel-Chromium Electrodes for the first pass on the clad side to reduce iron dilution.

And, *then*, use "132" Inconel Electrodes for the balance of the beads to get welds with all the high temperature strength and corrosion resistance of Inconel*—*at lowest cost.*

Assistance, if you need it, comes in two ways. First, from Inco's Technical Service Section. They'll gladly answer questions about welding the Inco Nickel Alloys. Second, from Technical Bulletin T-2, *Fusion Welding of Nickel and High Nickel Alloys.* Write for a copy today.

*Registered Trademark ®Chicago Bridges & Iron Company

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street New York 5, N. Y.



3. When the top's on, the entire job passes ASME requirements for pressure vessels. Two tensile tests, four side bend tests, and about twenty spot radiograph tests per vessel! The digester you've seen and another installed at the same time took 250 man-hours of welding, 400 lbs. of "142" 80/20 Nickel-Chromium Electrodes, and 200 lbs. of "132" Inconel Electrodes.

INCO TRADE MARK

Welding Products

Electrodes • Wires • Fluxes

THE
WELDING
JOURNAL

Editor
B. E. Rossi

Assistant Editor, Production
Catherine O'Leary

Officers of the Society

J. H. Humberstone
President
J. J. Chyle
1st Vice-President
C. P. Sander
2nd Vice-President
R. S. Donald
Treasurer
J. G. Magrath
Secretary
F. J. Mooney
Asst. Secretary
S. A. Greenberg
Technical Secretary

District Directors

1. *New England*
H. Hugo Stahl
2. *Middle Eastern*
D. B. Howard
3. *North Central*
Clarence E. Jackson
4. *Southeast*
A. E. Pearson
5. *East Central*
J. H. Blankenbuehler
6. *Central*
J. R. Stitt
7. *West Central*
A. F. Chouinard
8. *Midwest*
H. Jackson
9. *Southwest*
J. B. Davis
10. *Western*
R. H. Smith
11. *Northwest*
Clarence M. Styer

WELDING THE CHALLENGES OF TOMORROW

During the first half of this century the fruits of production nearly doubled. Electric power plants at the present time turn out 500% more electric current than they did twenty years ago with only 15% more workers. The demand of the future is for double the present power supply each decade, much of which will stem from nuclear power for ships, homes, industry, transportation and the unending new advances that mark progress. Now, Congress and the President have opened the way for the industrial development of the atom for peacetime application. This presents a challenge to the welding industry paralleled only by the material producer. Are we ready to meet this challenge?

Basic science is moving ahead. The application to engineering problems of isotope tracers is daily broadening our knowledge. Practical procedures for welding some of our new metals and their alloys offer new challenges. Bimetallic joints with predictable operating and corrosion resistivity characteristics are problems of the present challenge. We find unanswered questions as to properties of the joints in heavy thick material, such as the quench effect on welding and the residual stresses across the joint.

Undeniably, there are responsibilities including the responsibility of industry for alert management, adequate research programs, applied engineering and proper welding tools to meet the challenge of tomorrow.

Industry today is doing its best to meet this challenge. Hardly an organization exists that does not have in-plant training, supplementing the academic schools from which we obtain our workmen. This responsibility should, however, not be shunned by the workman. He should not place himself in the category of the buggy and whip makers at the start of the auto age who groused around rather than equip themselves to meet the challenge of a changing world. Industry and its workers must be ever cognizant of the technological advances being made through the application of new developments in science.

In this atomic era, both industry and its workers must avail themselves of the numerous opportunities presented; they must prepare themselves to maintain and ever accelerate the pace of industrial advancement, thereby speeding the lowering of product cost, raising the standard of living and attaining a more full life for all.

Monro B. Lanier
MEMBER
AWS BOARD OF DIRECTORS

Tempilstik°

FOR ALL HEAT-DEPENDENT OPERATIONS

looks like a crayon...

marks like a crayon...

tells temperatures like a precision instrument!

Sixty-three different compositions enable you to determine and control working temperatures from 113° to 2000° F.

TEMPILSTIK° marks on workpiece "say when" by melting at stated temperatures—plus or minus 1%.

Also Available in Liquid and Pellet Form ...Write Accessories Div. For Sample Tempil° Pellets ... State Temperatures of Interest—Please!

Tempil°
CORPORATION
132 WEST 22ND STREET
NEW YORK 11, N. Y.

How Tempilstiks° are used

● TEMPILSTIKS° are temperature-sensitive crayons of calibrated melting points. There are some sixty-five different TEMPILSTIKS° in the range from 113°F to 2000°F, each indicating a specified temperature, within a tolerance of plus or minus 1% of its rating.

The appropriate TEMPILSTIK° is selected and, for most applications, the work-piece is marked with it before heat is applied. On subsequent heating the crayon-like mark of the TEMPILSTIK° melts as soon as its temperature rating is reached.

The mark made by a TEMPILSTIK° may gradually change in color as heating progresses. The change in color, or in color intensity, is never to be interpreted as a temperature indication. The TEMPILSTIK° mark melts when its temperature rating is reached and only this change from the dry to the liquid condition is the significant temperature signal.

In some applications this simple method may not suffice because evaporation of the TEMPILSTIK° mark on prolonged heating, or its gradual absorption by the surface at high temperatures, may leave too little residual substance for unambiguous observation. In such cases stroking or touching the work-piece with the TEMPILSTIK° at regular intervals during the heating process is recommended. The TEMPILSTIK° will leave a dry mark at temperatures below its rating and a liquid streak when its temperature rating has been reached or exceeded. If the workpiece is not accessible for applying a TEMPILSTIK° during the heating process, then TEMPILAQ°, or possibly TEMPIL° PELLETS, should be used instead.

TEMPILSTIKS° will usually glide over unheated polished surfaces (like glass, polished stainless steel, etc.) without leaving an appreciable mark. Therefore, in applications that involve smooth or polished surfaces TEMPILSTIKS° should be used by touching or stroking the workpiece periodically during the heating process, as previously described, because a liquid streak will be made on contact as soon as the specified temperature is reached. Where it is necessary to mark a smooth work piece surface prior to heating, TEMPILAQ° should be used.

A hot radiating surface will appear relatively dark under intense illumination from an external source, and this fact can be utilized to improve recognition of the temperature signal against a red-hot background. The use of TEMPIL° PELLETS or TEMPILAQ° instead of TEMPILSTIKS° will further improve visibility under these conditions.

On rapidly moving objects, like magnesium or aluminum sheet during spinning operations, it is impossible to see whether the applied TEMPILSTIK° leaves a dry or melted mark. However, with a little experience operators quickly learn to sense the smooth gliding of a TEMPILSTIK° over a surface which is hot enough to melt it on contact, as contrasted to the frictional drag on a cooler surface. If the top of the TEMPILSTIK° is brought in contact with the moving metal surface for a brief moment at a time, and with light pressure only, the heat contribution of friction is trivial enough to be ignored.

The above described "sensing technique" may also be employed on hot radiating surfaces where the bright background makes it difficult to distinguish whether or not the TEMPILSTIK° mark had melted.

An appropriate series of TEMPILSTIK° marks, applied to the workpiece or surface under investigation before heating begins, will provide a record of the maximum temperature attained during a process or operation. Subsequent examination will show that all TEMPILSTIK° marks up to a certain temperature rating had melted, while those of a higher rating had not. The maximum attained temperature must consequently lie somewhere in the interval between the highest melted and the lowest unmelted TEMPILSTIK° rating.

The temperature distribution and isothermal boundaries of surfaces such as furnace walls, melting ladles, cement kilns, etc., can be established by using an appropriately chosen series of TEMPILSTIKS° to draw a pattern of lines (parallel, concentric, radial, etc.) on the area under investigation. The heat conduction along a surface can be effectively studied by the progressive melting of suitably chosen TEMPILSTIK° lines. Caution must be exercised not to permit the mark made with one TEMPILSTIK° rating to cross or overlap the mark of a dissimilar TEMPILSTIK°, as such a mixing of different TEMPILSTIK° marks would destroy their accuracy.

TEMPIL° products will give good results in induction heating and in ionized air, as well as in the presence of static electricity about electrical equipment, where electrical means of measuring temperatures often function erratically.

View showing continuous welded rail on a 2-deg curve

AN APPLICATION OF PRESSURE WELDING TO FABRICATE CONTINUOUS WELDED RAIL

Railroads adapt continuous welded rails for smoother riding tracks and decreased maintenance

BY DAVID C. HASTINGS

SYNOPSIS. During the last 20 years, the American railroad industry has spent a considerable amount of time in the research and development of all kinds of mechanized equipment in an effort to combat constantly increasing costs as a result of the basic wage in the industry being triple what it was prior to that time. This work has been done in all departments of the railroads; however, some of the most outstanding advances and achievements have been made in the field of maintenance and construction work. As an example, it was a known fact that if the rail joint could be eliminated a considerable number of man-hours of maintenance labor would be saved. Therefore the railroad industry, together with certain interested manufacturers, developed the pressure welding process with steel rails to the point that continuous rail in lengths of over a mile became a reality instead of a dream. The pressure weld is a highly technical and refined development of the old-fashioned blacksmith weld since no fluxing agents are used and no additional metal is necessary. The weld is made by pressing two rails together under a hydraulic pressure of 3000 psi and at the same time applying heat until the temperature of the steel reaches 2250° F, at which point the steel becomes plastic and the molecules of metal knit together to form a weld. The article which follows explains in somewhat more detail the necessity for such a development as well as the process itself.

David C. Hastings is Superintendent, Richmond, Fredericksburg & Potomac Railroad Co., Potomac Yard, Alexandria, Va.

Presented at 1955 AWS National Fall Meeting in Philadelphia, Pa., October 17–21.

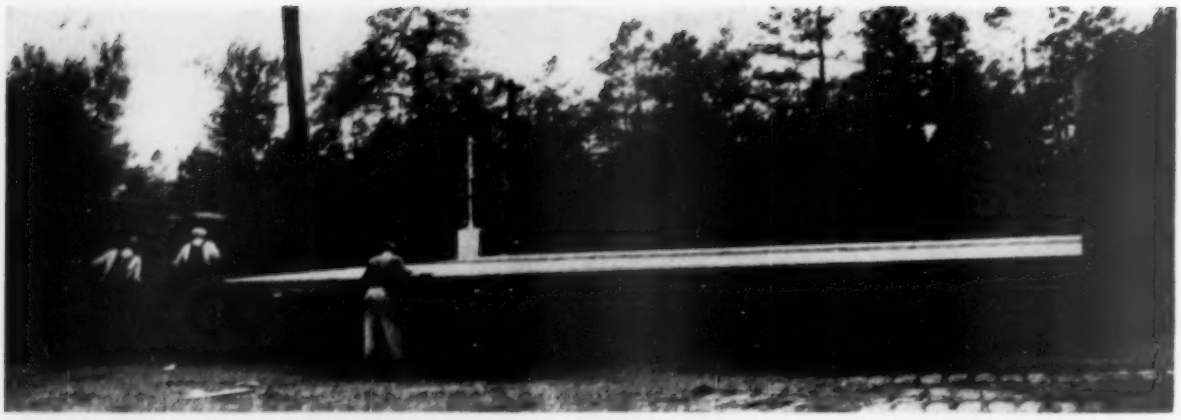


Fig. 1 View showing storage pile with one rail being moved into the saw

Fig. 2 View showing the sawed ends of the rails being examined for defects and cleaned with carbon tetrachloride

Early Program

During the first 100 years of the railroad industry's progress men of the past generation made outstanding advances. Improvements were made in grades and alignment. New bridges were built to take care of higher operating speeds and heavier locomotives. Multiple track construction progressed in the heavy traffic areas of the east to keep pace with the constant demand for better service as car loadings continued to increase. The track structure was improved which involved better ballast, ties, rail and other track materials. Stations were improved and new yards constructed with car retarders, electrically operated switches and other mechanical devices.

During the next ten years the greatest advancement consisted of the diesel-electric locomotive practically replacing the old steam engine. Also new, lightweight, streamlined, air-conditioned passenger trains were added in place of the former standard type of equipment. This new equipment enabled the industry to offer better service which resulted in demands for higher speeds and more comfortable riding qualities. During this same ten-year period organized labor went through a series of successful wage negotiations that resulted in the basic wage of the industry being tripled.

Latest Developments

Immediately the initiative, enthusiasm and resourcefulness of the railroad industry's engineering depart-

ments were called upon which resulted in new developments on the physical properties everywhere. Higher speeds required new studies to be made of superelevation and new tables to be made up compromising somewhere between equilibrium and safe speeds so as to have good riding qualities and still consider the all-important economic factor of rail wear. Increased operating costs due to wage increases resulted in the development of an incredible number of labor-saving machines. Also these increased costs have caused maintenance engineers to study every possible means of reducing man-hours. In this study the track structure containing 270 rail joints to the mile presented a most challenging problem.

Need for a Welded Joint

A rail joint is the weakest part of the track structure. Six-hole, 36-in. angle bars were a great improvement in 1929 but the joint was still there. To keep the joint in good surface required man-hours of maintenance labor which had to be expended wisely since as a result of increased costs management demanded a reduction in operating expenses. It became quite apparent that if the rail joint could be eliminated not only would man-hours of maintenance be saved but also the initial material costs represented in the joint bars, the bolts, the lock washers and the signal circuit bond wire. Maintenance engineers and their friends in the supply field went to work and developed the pressure-type butt weld. This was successfully tested by the research and test section of the American Railway Engineering Association at the University of Illinois and placed on the market as a patented process. There have been other types of welds developed which have met with limited use, however the pressure butt weld is the only type that has been extensively used in high-speed track to date in this country.

Pressure Butt Welding

Pressure butt welding is a solid phase weld and is not liquid phase. It is a highly technical and refined development of the old-fashioned blacksmith weld since no fluxing agents are used and no additional metal is added. The weld is made by pressure alone. Two evenly matched clean and dry rail surfaces are brought together, end to end, by a hydraulic pressure of 3000 psi and then heat is applied to the ends of the rails by a specially developed oxy-acetylene multi-tip torch until the temperature of the steel reaches 2250°F. At this temperature the steel becomes plastic or pliable and as a result of the pressure being applied, a migration of the molecules of the metal occurs across the face of each rail end and this action causes the two rails to bond together. The pressure is applied until each rail moves into the other $^3/_8$ in., or a total of $^3/_4$ in. has been traversed by the two rails, after which the pressure is released. The weld is then complete and is ready for further processing. The entire operation of butt welding, as well as laying continuous welded rails, is most interesting and will now be described briefly.

The track to be laid with welded rail must be chained off so as to locate the points where insulated joints must be installed for the signal circuit. This chaining must be done with extreme accuracy. The actual rail layout is then drawn up and the welding schedule prepared. The first string of rails welded becomes the last to be loaded and the first to be laid, hence the necessity of the installation layout ahead of time.

Rails are ordered from the steel mill for welding with "blind ends," that is to say no holes drilled, no chamfering, no end hardening and no classification marking. They are unloaded in storage piles (see Fig. 1) at the welding site with all the mill brands facing the same way so as to eliminate any slight difference in perfect contour which might exist as a result of rolling. Rails of like classification are piled together, namely, High Carbon, Firsts, "A"'s and Seconds. The first operation is the mechanical saw which cuts simultaneously the two rail ends so as to make them fit perfectly. This sawing is accomplished with the ends slightly lower than the centers to compensate for the tendency of the rail to cock up when the pressure weld is made. This must be very carefully controlled to insure good surface on the finished rail.

After the ends are sawed they are examined to see that no defects exist and that all oxidized surfaces have been removed (see Fig. 2). The rails then move into the welding machine. This machine is equipped with

Fig. 3 View showing a welded joint after the upset on the head and the base has been removed

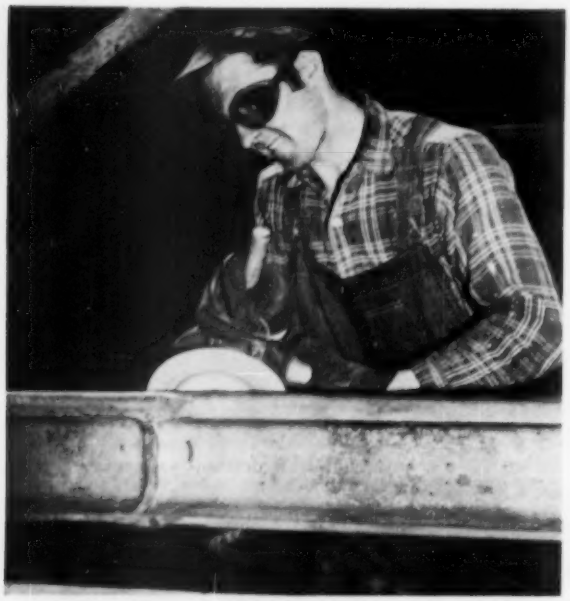


Fig. 4 View showing the grinding operation to restore the head of the rail to its original contour

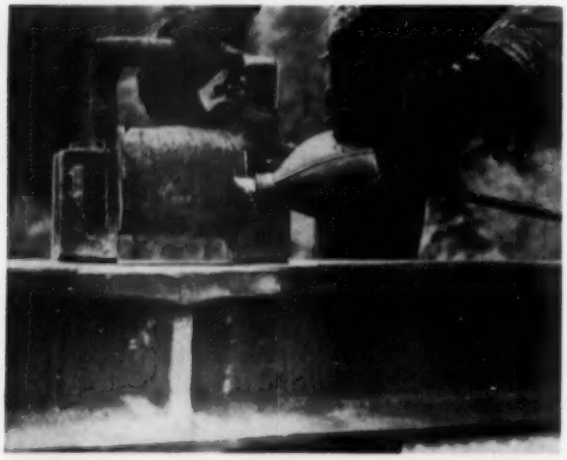


Fig. 5 View showing a completed joint being tested by the magnetic powder process

a multi-tip torch which travels back and forth across the ends of the rail heating the entire end gradually and uniformly. The rail ends are cleaned with carbon tetrachloride to remove all foreign matter and are placed end to end and clamped. An electrically operated hydraulic ram then applies the 3000 psi pressure and the torches are ignited. The torches are fed oxygen and acetylene from a bank of cylinders consisting of 20 of each and are water cooled to prevent overheating after long use. Approximately 20 cu ft of each gas are consumed a minute while the heat is being applied. A weld takes about five minutes to complete once the rails are set. When the rail ends heat to a temperature of 2000° F a noticeable upset begins to appear caused by the rails beginning to knit together. When the temperature reaches 2250° F the condition of the rail is plastic enough that the pressure causes the rails to completely weld together and they move into each other a distance of $^3/_8$ in. When the total distance traversed by both rails is $^3/_4$ in. the pressure is released and the weld has been made.

It is very important that the rails be kept in good surface and line while the ends are hot and therefore the conveyor line is set to both grade and alignment with an instrument. It is set level leaving the welding machine and with a slight vertical sweep leaving the normalizing machine to allow the rails to cool without the joints being cocked up.

As a result of the weld, each rail is $^3/_4$ in. shorter than it was and this metal lost as a result becomes a bulge or upset around the entire periphery of the rail section. The next process is the shearing off of this upset. A set of electrically operated hydraulic shears having a total pressure of 15,000 lb are placed on the rail and shear off the upset on the head of the rail. Special type cutting torches are then used to cut it off on the edges and the bottom of the base of the rail (see Fig. 3).

The rail then moves on to the normalizing station. When it reaches this point, the temperature is approximately 900° F. The normalizer is equipped with another multi-tip oxy-acetylene torch which is used to bring the temperature of the weld back up to 1550° F. There are two reasons for normalizing the weld: first, to refine the grain structure in the area affected by the heat applied during welding and second, to restore the hardness in the heat-affected zone to equal that of the unheated rail. The head of the normalizer is set at an angle of 45° to the running surface of the rail so that the tendency of the soft zone to flow later on after installation under repeated wheel loads will be reduced.

Following the normalizing process the rail is allowed tocool in the atmosphere and the remainder of the upset metal is ground off with manually operated grinding machines (see Fig. 4). The weld is then tested by the

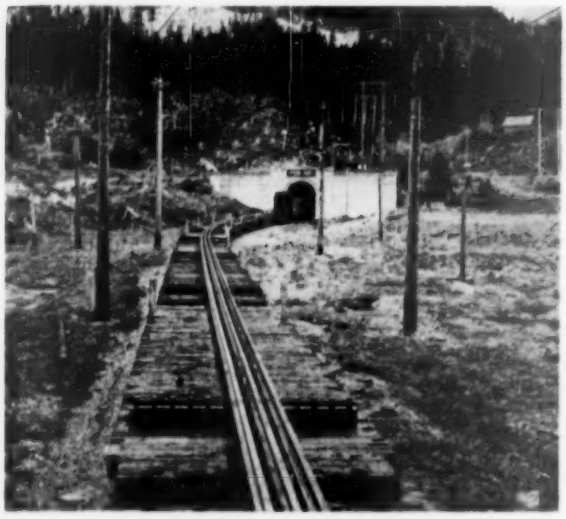


Fig. 6 View showing rails being transported to point of application on flat cars

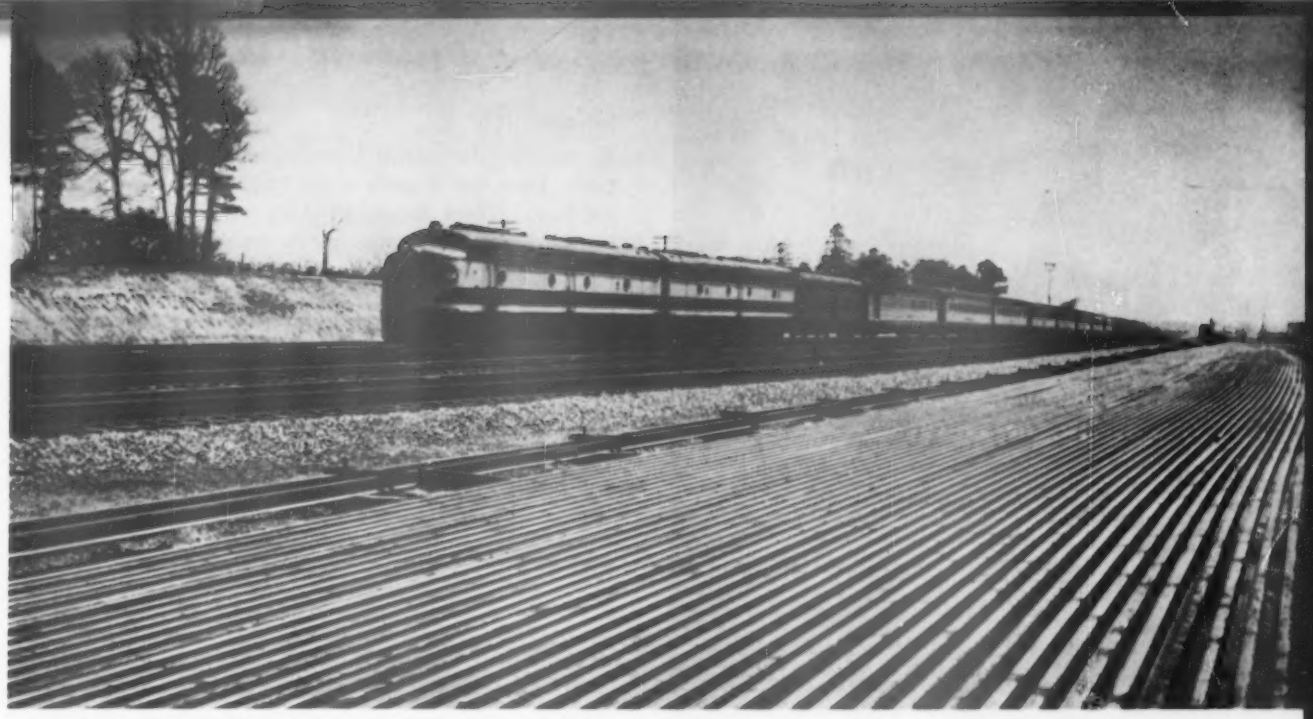


Fig. 7 View showing 12 linear miles of rail stored at the welding site

magnetic powder process and if no cracks are found the process is complete (see Fig. 5). Prior to actual laying, however, each welded joint is again tested by an electronic detector to check for defects.

Problems of Anchorage

The number of rails welded together can be varied depending on the desires or limitations of the railroad. Thirty has been picked as an arbitrary number and experience has proved that it is a good choice. Thirty rails welded together make a continuous rail 1167 ft $10^{5}/_{8}$ in. long. These rails have in turn been field welded together and there are continuous rails in track in use today on some railroads as long as ten miles.

The entire theory on expansion and contraction and former practices of laying rails with suitable expansion shims at the joints has been changed as a result of the welding of rails. If the coefficient of expansion of steel is multiplied by its modulus of elasticity, then by the maximum temperature range expressed in degrees Fahrenheit, and finally by the cross-sectional area of the rail expressed in square inches, the result is the total stress in a piece of rail due to a certain temperature change. This is the stress that has to be overcome by adequate anchorage in order to be able to use welded rail on any trackage. It can readily be seen that in laying conventional type rail, if due to the anticipated temperature range a $^{1}/_{8}$-in. shim should be used when a piece of continuous welded rail is laid containing 30 rails, it would not be possible to leave a gap at the end of $^{30}/_{8}$, or $3^{3}/_{4}$ in. Therefore, the welded rail is laid with no gap and is held in place with rail anchors. If the resistance of one tie in the ballast in pounds is divided into the stress obtained from the previously mentioned formula the number of ties to be anchored to withhold the total stress can be determined. This method allows the value of the frictional resistance in the tie plates, as well as the strength of the $1^{1}/_{8}$-in. bolts in the joint in double shear, to be used as a factor of safety.

If then the rail is anchored in its normal manner to prevent creepage and is anchored with enough additional anchors to hold the tendency to expand or contract, it can be used without any gap at the joints at all. This results in the rail not being allowed to expand or contract due to temperature changes which in turn places an initial stress in the rail with no load. This initial stress plus the normal load applied to rail is well within the working limit of steel. A standard practice on anchorage has been field tested by the AREA Committee on Continuous Welded Rails and issued to the industry in the form of a recommended practice which is being generally followed today.

If the welded rail is laid at a mean temperature then the amount of initial stress in the rail is materially reduced because of the fact that the range of temperature is much smaller. Installation temperatures of about 70 to 80° F are ideal since the result is a maximum temperature range in this area of about 40° causing compression and 70° causing tension.

The long continuous welded rails are transported to the point of application on flat cars and are unloaded by pulling them rail by rail off these flats (see Fig. 6). The actual laying operation then is similar to any rail renewal job which today is a highly mechanized process.

By eliminating joints with continuous welded rail some railroads have produced better riding track, more comfort to their passengers, smoother handling of perishable or fragile freight and, above all, have found a definite advantage in decreased maintenance which reflects in lower operating costs (see Fig. 7).

Typical projection welding application using 500-kva (3ϕ) press welder

LOWER PART COST BY PROJECTION WELDING

Cost savings and increased production are experienced when certain types of farm implement parts, formerly fabricated by arc welding, are redesigned to be fabricated by means of resistance projection welding

BY C. H. BURGSTON

C. H. Burgston is Welding Division Supervisor, Materials Engineering Dept., Deere & Co., Moline, Ill.

Presented at AWS National Fall Meeting in Philadelphia, Pa., Oct. 17–21, 1955.

Introduction

In the manufacture of farm implements and tractor parts, great use is made of arc welding and resistance welding. Where the design of arc weldments, forgings or castings lend themselves to design for resistance welding, substantial cost savings can generally be realized. During the past four years for example, some 250 different parts were redesigned and fabricated by means of resistance projection welding. These parts in general would be classified as heavy sectioned projection weldments.

The development of parts for projection welding has been the joint effort of factory product designers, methods men and the welding laboratory.

Projection welding is a resistance welding process in which coalescence is produced by the heat obtained from the resistance to flow of electric current through the work parts held under pressure by copper electrodes or platens. The resulting welds are localized at predetermined points by the design of parts to be welded. This is accomplished by projections, embossments or natural intersections which direct the flow of welding current from one work part to another. Coalescence (or weld) by definition is to grow together in one body.

In resistance welding processes the following fundamental heat formula applies:

$$\text{Heat} = I^2Rt$$

I = current
R = resistance
t = time

Heat then varies directly as the square of the current, directly as the resistance and directly as the time. Since resistance R is low, time t is short, current I must be relatively high to heat work to welding temperature.

Welding currents as low as 3000 amp are used for 32 gage steel welds and as high as 70,000 amp (or more) for heavy sectioned projection welds.

Projection welders range in size from 50 to 600 kva (and larger) and can be single-phase or three-phase welders. Three-phase welders are of two principal types—frequency converter and dry disk rectifier welders. The frequency converter has greater flexibility and is more versatile for production welding.

Electronic timer controllers, for controlling current magnitude and duration, are furnished synchronous or nonsynchronous on single-phase welders and fully synchronous on three-phase frequency converter welders. Welding pressures on welders are generally controlled by air cylinder or hydraulic cylinder mechanisms.

In single-phase welders, line voltage of 220 or 440 v, 60 cycle, single phase is passed through a transformer to produce low voltage, high amperage welding current. The secondary or output voltage of a single-phase a-c welder transformer is essentially the input voltage divided by the transformer turns ratio. Projection welders usually have a one-turn secondary.

In three-phase frequency converter type welders,

60-cycle line current is converted (by means of electronic tubes and transformer action) to produce 5 to 20 cps high amperage low voltage secondary or welding current.

In both cases, heat to produce fusion or weld is a function largely of induced secondary welding current and voltage.

A standard resistance welder has three basic requirements:

1. Electrical circuit to transmit the desired amount and intensity of current.
2. Mechanical system to hold work pieces while pressure or force is applied.
3. Electronic controls for weld factor timed intervals.

Weldability of Steels for Projection Welding

Weldability is defined as the capacity of metal to be welded under fabrication conditions imposed into a suitably designed structure and to perform satisfactorily for intended service.

Low carbon steels (0.30% max carbon) are commonly used in resistance welding and such steels have good weldability. However, if resistance welding were confined to low carbon steels only, its use would certainly be limited in the fabrication of farm equipment parts.

As the carbon of the steel increases above 0.30%, the hardenability of steel increases and the easy weldability decreases. Therefore, special procedures have to be used in welding medium or higher carbon steels.

In welding of hardenable steels, martensite and high hardness occur in the weld heat-affected zone. The higher the carbon content of base steel, the greater the percentage of high carbon martensite present and the higher the hardness. Martensite is a brittle constituent formed when the base steel is hardened by the quenching action of adjacent cold metal.

It is desirable that martensite does not exceed 10% and, if present, is in the form of tempered martensite. The weld heat-affected zones to be preferred would have no martensite and hardness not over Rockwell C-30.

High hardness and martensite in heat-affected zones can be avoided by using impulse welding or high heat input postheat and thus prevent the critical base steel cooling rate that forms martensite.

Under controlled conditions, 1035-1045-1055-1070 steels have been successfully projection welded. Some of these jobs are (1) 1018 steel studs to 1045 steel in combine rasp bars, (2) 1045 to 1045 steel in harrow bars, (3) 1070 to 1070 steel in planter check forks.

The resistance welding of rerolled rail steels is not recommended. It is possible to resistance weld some types of resulfurized steels.

Scale-free clean surfaced steel should be used in production projection welding. Cleaning costs are not high and clean steel offers three important advantages; namely, (1) uniform heat input to parts, (2) lower copper die maintenance cost, (3) uniform welded joint strength. Scaly surfaces cause resistance variation between parts which affects current flow and weld strength.

Design for Projection Welding

A famous stylist-designer made the statement that product designers should follow more of the designs of nature; for example, the growing tree with its tapered trunk and flowing branches; that is, build parts with symmetry and beauty. It was stated that by so doing designs with highly localized stresses could be avoided. True, all part designs are not shaped like a tree but nevertheless the thought is well taken.

Product designers should develop basic designs for projection welding and not merely convert from a previous design. If done, costs will generally be lower and usually a better product results.

Projection welded parts in general have good appearance. The appearance of a weldment is largely up to the designer. Product engineers can design and properly place projections to develop required joint strength. Several projection welds can be made with one stroke of the welding machine ram. Hence, welds can be spaced closer together than in spot welding because there will be no shunting effect.

In the projection welding of sheet and plate steels, standards for projections sizes are available. AWS Recommended Practices for Resistance Welding covers recommended projections for sheet and plate sections up to 0.25 in. and individual companies have developed their own standards up to 0.50 in.

PROJECTION WELDING STANDARDS
FOR LOW CARBON STEEL

MATERIAL THICKNESS-T		PROJECTION DIAMETER-D		PROJECTION HEIGHT-H	
BUICK EQUIV.	U.S.S.G.	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM
0.012	30	0.075	0.080	0.015	0.020
0.014	29	0.075	0.080	0.015	0.020
0.015	28	0.075	0.080	0.015	0.020
0.016	27	0.075	0.080	0.015	0.020
0.018	26	0.090	0.095	0.020	0.025
0.021	25	0.090	0.095	0.020	0.025
0.024	24	0.090	0.095	0.020	0.025
0.027	23	0.105	0.110	0.025	0.030
0.030	22	0.105	0.110	0.025	0.030
0.033	21	0.105	0.110	0.025	0.030
0.036	20	0.120	0.125	0.030	0.035
0.042	19	0.120	0.125	0.030	0.035
0.048	18	0.135	0.140	0.035	0.040
0.054	17	0.135	0.140	0.035	0.040
0.060	16	0.150	0.160	0.040	0.045
0.067	15	0.150	0.160	0.040	0.045
0.075	14	0.170	0.185	0.045	0.050
0.090	13	0.170	0.185	0.045	0.050
0.105	12	0.200	0.215	0.050	0.055
0.120	11	0.220	0.235	0.050	0.055
0.135	10	0.230	0.250	0.052	0.060
0.150	9	0.250	0.270	0.052	0.060
0.165	8	0.270	0.290	0.057	0.065
0.180	7	0.290	0.310	0.057	0.065
0.195	6	0.310	0.330	0.062	0.070
0.210	5	0.330	0.350	0.062	0.070
0.225	4	0.350	0.370	0.067	0.075
0.248	3	0.370	0.390	0.067	0.075
0.265	2	0.390	0.410	0.072	0.080
0.281	1	0.410	0.430	0.077	0.085
0.312	0	0.450	0.480	0.080	0.090
0.343	2.0	0.490	0.520	0.085	0.095
0.375	3.0	0.530	0.560	0.090	0.100
0.406	4.0	0.560	0.590	0.095	0.105
0.437	5.0	0.600	0.630	0.100	0.110
0.468	6.0	0.640	0.670	0.105	0.115
0.500	7.0	0.680	0.710	0.110	0.120

Fig. 1 Table of projection welding standards

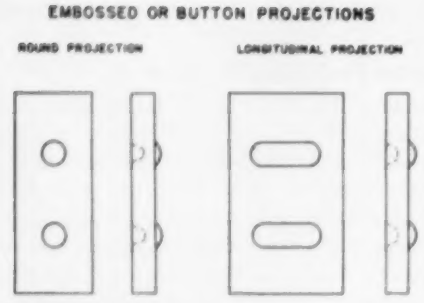


Fig. 2 Button projections

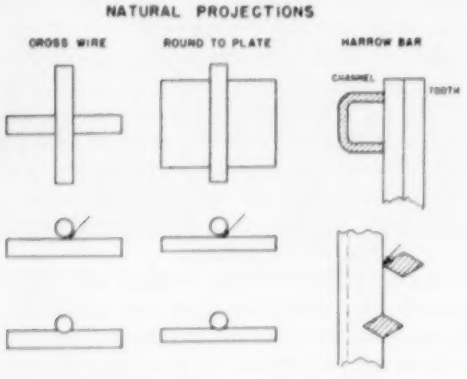


Fig. 3 Natural projections

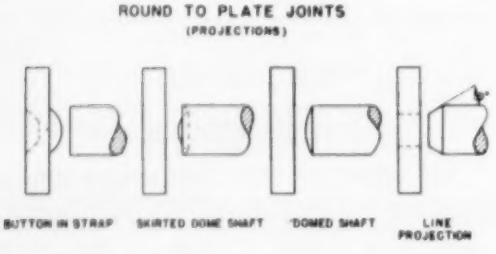


Fig. 4 Rounds to plates series

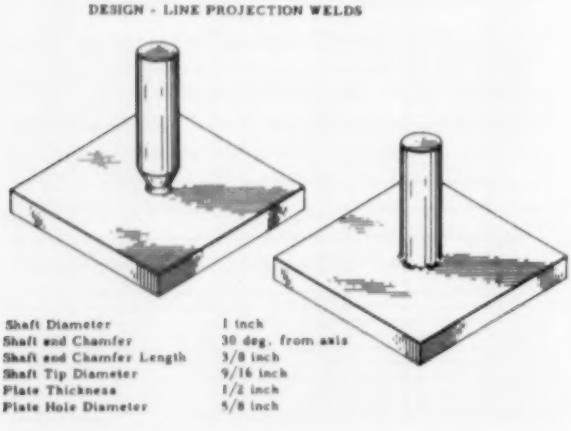

DESIGN - LINE PROJECTION WELDS
Shaft Diameter 1 inch
Shaft end Chamfer 30 deg. from axis
Shaft end Chamfer Length 3/8 inch
Shaft Tip Diameter 9/16 inch
Plate Thickness 1/2 inch
Plate Hole Diameter 5/8 inch

Fig. 5 Line projection weld

As sections increase in thickness, the diameter and height of projections are increased to develop required strength. On dissimilar sections, the projection is generally placed on heavier section. Projections are embossed both cold and hot depending upon section thickness and steel chemistry.

In Fig. 1 is one standard for projections covering sheets and plates up to 0.5 in. thicknesses.

In Fig. 2 is shown typical round and elongated projections embossed in plate.

In all projection welding, it is necessary to have point or line contact to start a weld. Button tips to flat plate is one example. Other steel parts, when located for welding, have natural projections due to their geometry. In Fig. 3 will be found examples of natural projections—cross wire joint and harrow bar joint.

In welding large rounds to plates, several projection designs have been used as illustrated in Fig. 4.

The series includes (1) button on plate, (2) dome on shaft end, (3) skirt dome on shaft and (4) 30° chamfer on shaft end into plate hole.

In Fig. 4, designs 1, 2, 3, welds are located at positions of maximum stress. In the line projection welded joint, design 4, this condition is largely removed.

In physical tests made on joints, the latter (design 4, the line projection weld) has been found to be the best under static or dynamic loading conditions (see Fig. 5).

Line projection welds should be well planned. Shaft end has 30° chamfer, the chamfer length should be 75% of plate thickness. Plate hole should be about $^1/_{32}$ in. in diameter larger than the shaft-end tip diameter. Holes can be drilled or punched. These welds are self-locating and elaborate fixtures in welding are not required. Best welds produced have some flash present. In production welding, as dies wear, some shaft marking is encountered. In the case of shaft bearings, shafts should be finished, turned or ground after welding.

Shaft-plate joints, with line projection welds, have proved to be satisfactory in field service.

Resistance Welding Laboratory

In the development of parts for projection welding, it is not very satisfactory to try to work out an experimental job on a busy production welder. The correct design and proper weld are seldom developed on the first trial with a new weldment and hence several welding trials are often necessary. This tends to disrupt production welding. Consequently in our company, the decision was made in 1950 to set up a Resistance Welding Laboratory which was to be devoted exclusively to experimental development work.

The welding laboratory is a division of the Materials Engineering Department. The aim in starting the laboratory was to work with the factories in developing better implement and tractor parts for current machines at lower cost by using the projection welding process.

A 300-kva single-phase combination spot and projection welder, with a 5B nonsynchronous timer-controller, was selected (see Figs 6 and 7). This welder

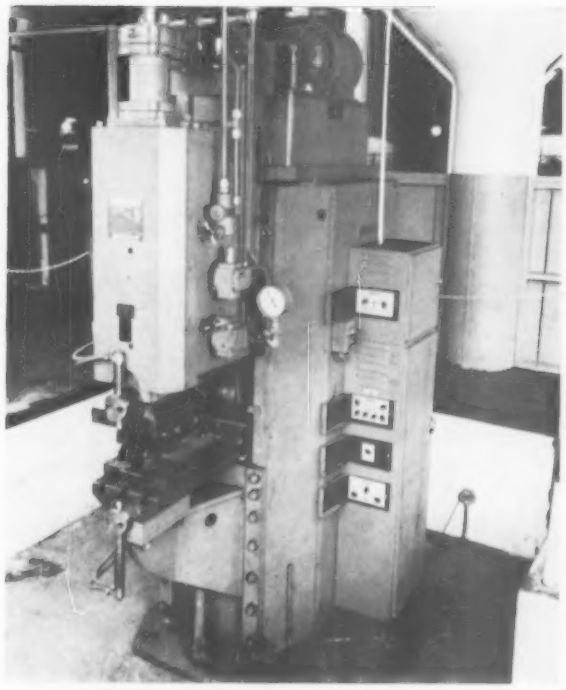


Fig. 6 300-kva (1ϕ) press welder

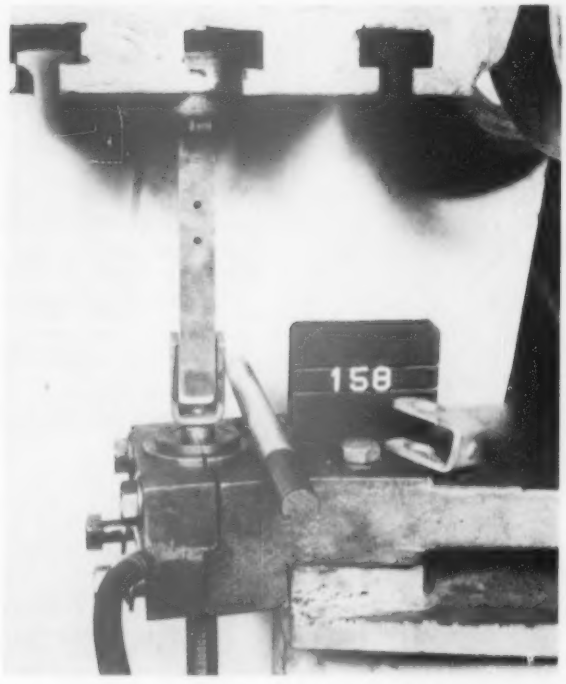


Fig. 7 300 kva (with short knee)

has a regular lower knee and a separate special lower knee which accommodates a series of copper collets to vertically clamp all rounds $^1/_2$ to $1^3/_4$ in. in diameter. This setup is used to experimentally weld round shafts to plates of which designs there are many. For smaller welding jobs, a 150-kva press welder is available.

Specifications of 300-kva single-phase press welder are as follows:

Throat depth, in.	18–24
Throat gap, in.	18
Transformer heat taps	16
Phase shift heat control	
Secondary current, amps	76,000
Hydraulic ram pressures, lb.	2500–20,000
Electronic timer controller	
NEMA—5B Nonsynchronous Sequence Timer (single or impulse welding)	
Slope control	
Postheat controls	
Ignitron tube contactor	

When experimental welds are being produced in the welder, accurate welding cost estimates can be made. Compensation for production fixturing and floor-to-floor time can be easily made. Also, electrical determinations can be made which will establish the correct welding machine size for production welding.

Laboratory records of experimental welding trials are useful when developing production welding schedules on either single-phase or three-phase factory welders.

A welding procedure record, together with a photograph of welding setup used, is kept on every experimental weldment. The optimum welding schedule is based on a good weld end-product, a strong weld to match service requirements. A yardstick of quality comprises (1) weld must "pull a good slug," (2) penetration must be adequate, (3) hardness must not be excessive and (4) recrystallization of grains must be developed across the weld faying surface. Optimum weld-procedure-schedules are developed to produce the strongest weld in the shortest weld machine time.

In Fig. 8 is shown Resistance Laboratory Welding schedule record on an experimental weldment.

In the laboratory, the following facilities for physical testing and electrical determinations are available:

A. Physical tests
   1. Work bench and vise for hammer tests
   2. 75-ton press for tests
   3. Portable spot weld strip tester
B. Metallurgical microscope
C. Instruments
   1. Force gage
   2. Cycle recorder
   3. Brush magnetic oscillograph
   4. Pointer stop voltmeter
   5. Pointer stop ammeter, with clamp-on transformer

Great use is made of hammer testing and other physical tests in establishing adequate joint strength. However, the best yardstick of adequate joint strength is field performance. In the early stages, most projection weldments are proved out by tests on experimental machines in the field. An all-important ques-

Photo No. 219-220 RESISTANCE WELDING - EXPERIMENTAL LABORATORY REPORT File No. 355
MATERIALS ENGINEERING DEPARTMENT
DEERE & COMPANY
Date April 29, 1955

Plant John Deer Plow Works Part Name Axle & Shaft Assies Number of Assemblies Welded 8 + 15

Origin Johannsen-Sullivan-Calsen Part Number 3723-A-185 Steels Used 1055
Machine Two-way, 800 Series Plows

Type of Weld Natural Projection
Welding Machine Used 300 KVA (Exp.) Press Welder (single phase)
Electrode or Platen Material Class 2 Copper
Throat Depth - Machine 18" - 24"
Throat Gap 18"

Spot and Projection Welding
Section Dimensions 1-1/4" Rds
Weld Spacing

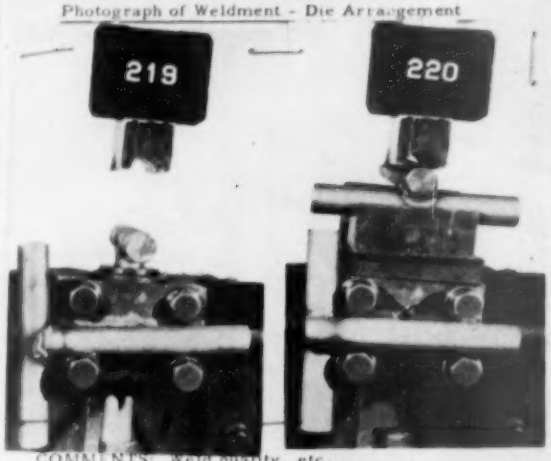
Projection	Dia.	Height Toe Weld	Length Cross Wire

Welding Schedule and Procedure

Pressure (lbs.)	8000	
Transformer Tap	H-8	
Transformer Turns	39-1	
Squeeze Time (Cycles)	40	2
Weld Heat Time (Cycles)	30	2
Cool Time (Cycles)	5	
Impulses	3	
Weld Duration (Cycles)	90	
Hold Time (Cycles)	20	
Phase Shift - Slope Control:		
Initial (%)		
Rate of Rise (%)		
Final (%)	89	

Post Heat Treatment: Chill Temper Phase Shift
Cycles none
Primary Current Reading 4.75 x 300 = 1425
Welding Secondary Current 1425 x 31 = 47025

Photograph of Weldment - Die Arrangement



COMMENTS: Weld quality, etc.
1. Four with 5/8" Rad. Dome - Too much flash
2. Four with no dome - flat cut-off-flash OK
Satisfactory - pulled slug under test
3. Cross wire made 90° & 81° Joints.

Fig. 8 Laboratory record and report

tion must be answered—is the weld joint strong enough, under static and dynamic loading, for the intended service?

One of the most important electrical determinations made in the laboratory is the determination of primary amperes required to make a weld. In making this determination, the clamp-on transformer is hooked on the line side of the welder transformer and is connected to pointer stop ammeter. The primary amperes are observed while the weld is being made. From the primary amperes, the secondary welding current is computed. Following is an example of such a computation made on a 300-kva single-phase a-c press welder:

Secondary welding current:

$$I_s = I_p \times \frac{E_p}{E_s}$$

I_s = secondary amperes
I_p = primary amperes
E_p = primary voltage
E_s = secondary voltage
Primary amperes (I_p) determined.....1600
Transformer turns ratio (H-5).....39–1
Secondary volts.....11

$$I_s = 1600 \times \frac{440}{11}$$

I_s = 64,000 secondary amperes or current required

The primary amperes and resultant secondary current demand in amperes and, the duty cycle at which welder is to operate, are of vital importance in selection of the proper kva rated transformer that will stand up under high-speed production welding service. Welding transformers are designed for a 50% duty cycle. RWMA defines name-plate rating as the "periodic rating based upon a 50% duty cycle and a *one minute integrating time*."

Experience has shown that actual production of welds per hour normally exceeds early estimates. Hence, the engineer should not be too conservative in selecting an adequate rated kva welder for the job.

As stated, some 250 implement and tractor parts have been developed for projection welding in production. In Figs. 9, 10, 11 there are shown 35 jobs which were changed over from arc welding to projection welding and in all cases, a better product at lower cost resulted.

Projection Welding Production

Of the many jobs developed for projection welding,

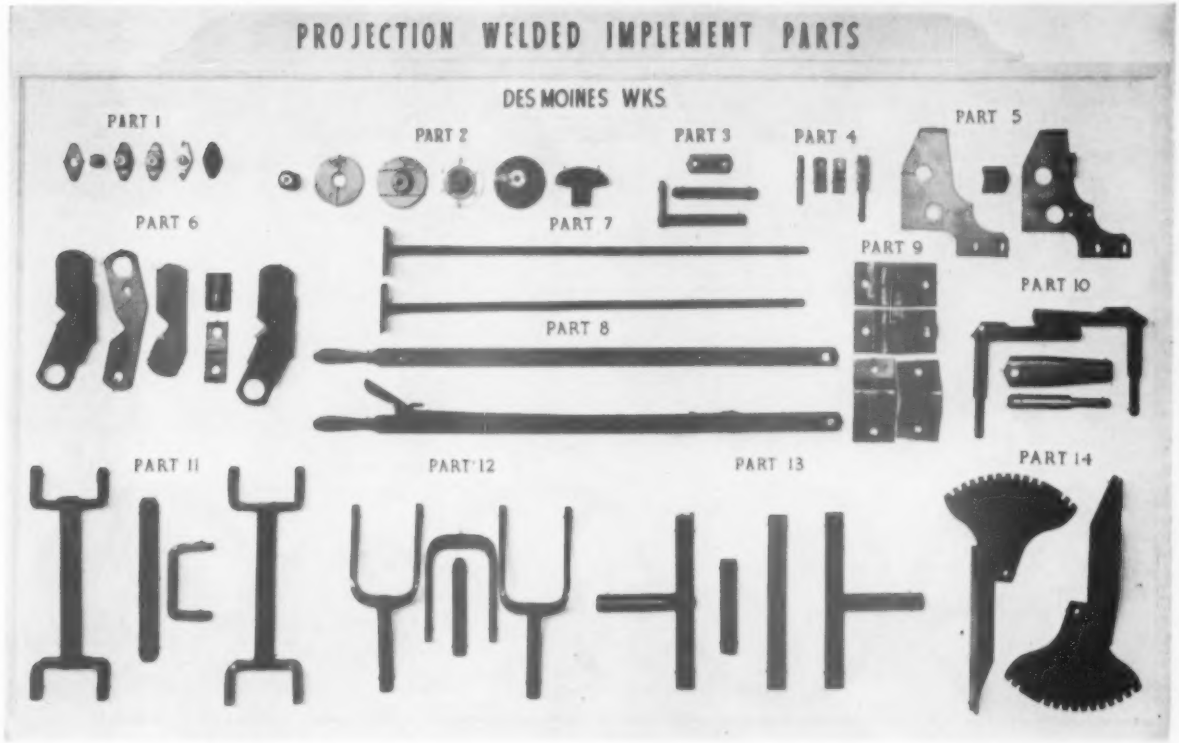


Fig. 9 Panel display 1

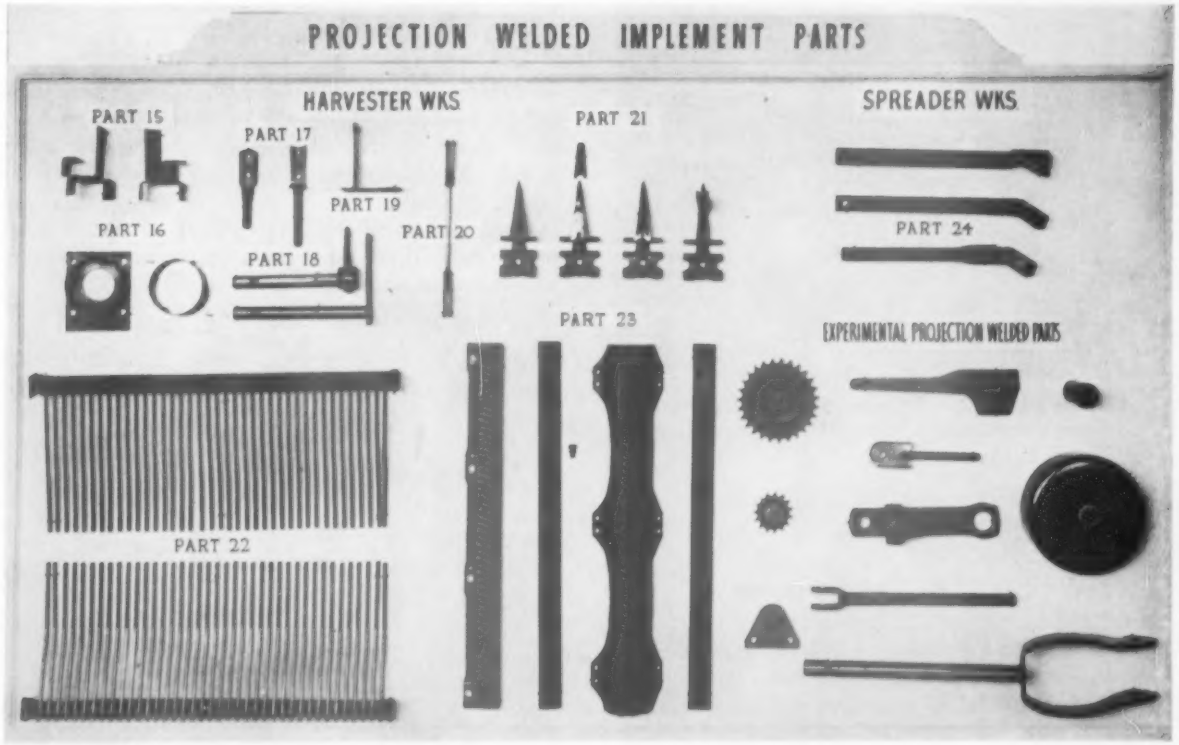


Fig. 10 Panel display 2

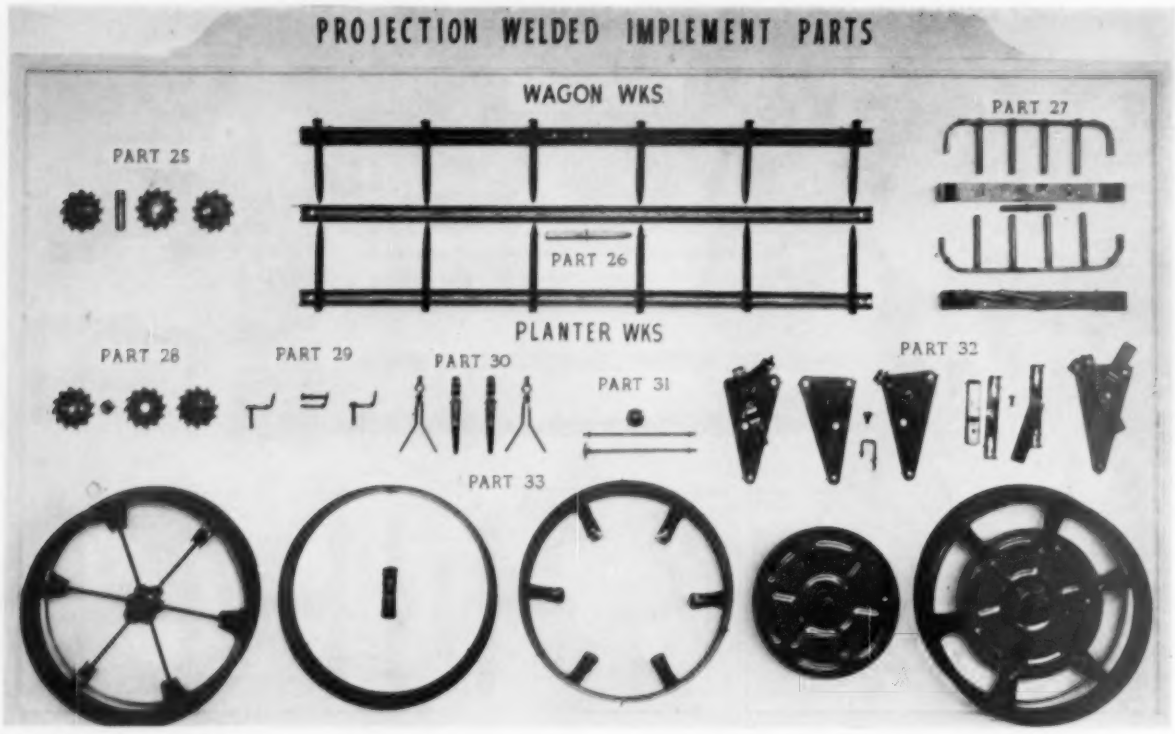


Fig. 11 Panel display 3

Fig. 12 Combine rasp bar (Steel 1018 cap-screw to 1045 bar) welded one shot and postheated

only a few can be illustrated and discussed in this paper. Four outstanding jobs projection welded in production are shown in Figs. 12 through 19.

Cost Reduction by Projection Welding

In the lead illustration and in Fig. 20 there are shown views of 500-kva three-phase press welders in production service. These welders have been in operation two and three years, respectively, one and two shifts per day.

In a program to make the best use of a relatively new process like heavy projection welding, a survey or study of parts suitable for projection welding can be made. Sample weldments can be made and field tested. This applies to both light and heavy sectioned parts. This plan assumes of course that experimental welding equipment is available.

Costs are accurately estimated in making sample weldments, for actual welding time is obtained. Assuming good production fixturing and simulated motion study, fairly accurate floor-to-floor time can be determined. Weld production per hour is conservatively estimated, using proper delay factors. Costs are available on parts replaced. Projected against total parts produced per year, savings in costs and welding man-hours are obtained.

Cost Studies—Seven Production Jobs

Based on 250 implement parts developed using

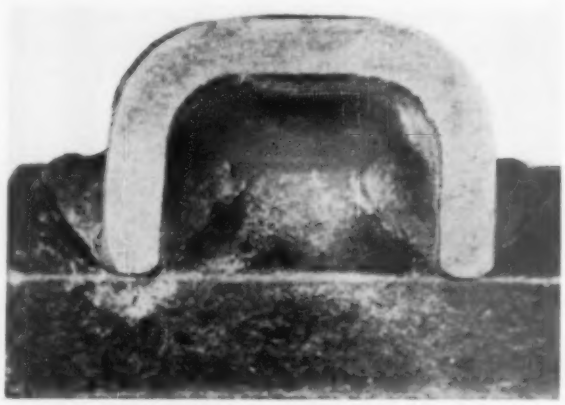


Fig. 13 Harrow bar joint (Steel 1045 to 1045)

Fig. 14 Production welding of harrow bars—impulse welding—no postheat (six welds made in 50 sec)

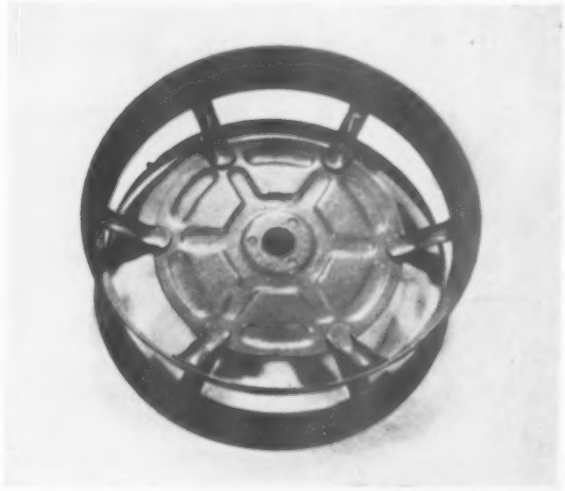


Fig. 15 Planter press wheel assembly (Steel 1020—projection on spoke)

Fig. 16 Planter press wheel, operation 1 (welded assemblies per hour—100)

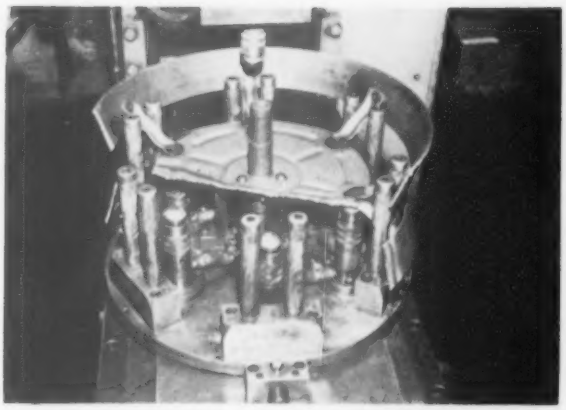


Fig. 17 Planter press wheel, operation 2 (welded assemblies per hour—50)

Fig. 18 Mower rock guard assembly (Steel 1030—projection on lip)

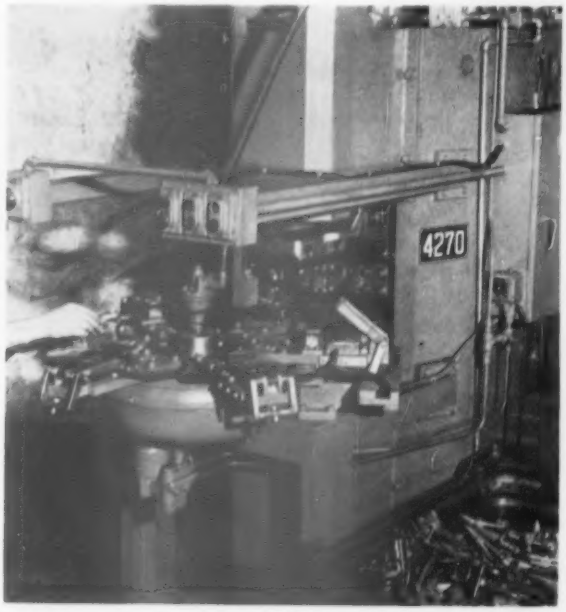


Fig. 19 Production welding of guards using indexing fixture—1200 welds/hr

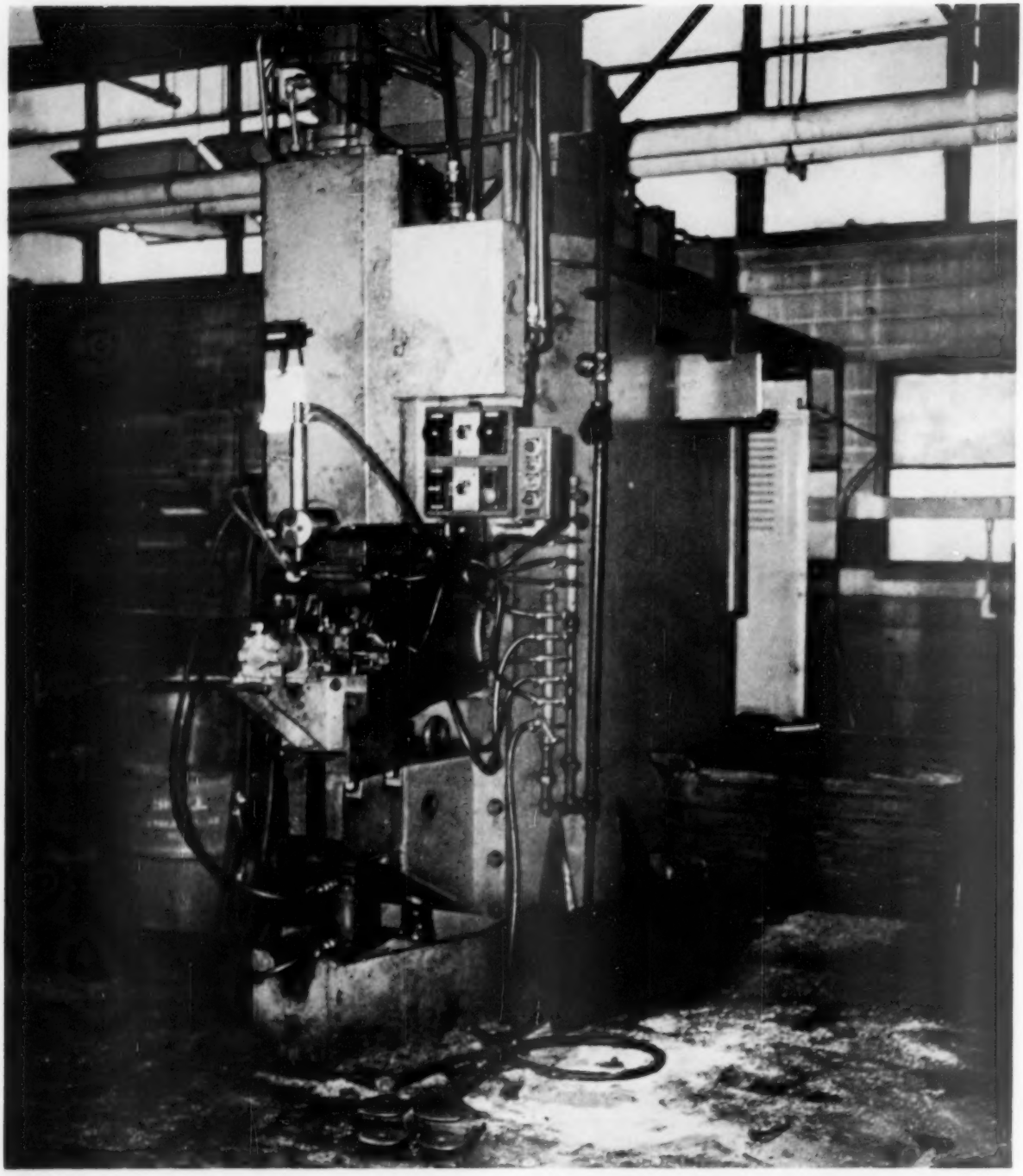


Fig. 20 500-kva (3ϕ) press welder

projection welding, about 90% of these parts are in production.

The production and cost studies which follow are based on seven production welded jobs, a total of 463,000 welded assemblies—the year's production:

Fig. 21, Job 1—Frame connecting bar–line projection weld (Steel 1045–1035); welded assemblies per hour, 60 (two operations)

Fig. 22, Job 2—Gage wheel yoke–line projection weld (Steel 1055); welded assemblies per hour, 250

Fig. 23, Job 3—Adapter (button in strap) (Steel 1020); welded assemblies per hour, 200

Fig. 24, Job 4— Stub beam (Steel 1045)–natural projection weld; welded assemblies per hour, 215

Fig. 25, Job 5—Lever (Steels 1035 to 1020)–line projection weld; welded assemblies per hour, 250

Fig. 26, Job 6—Ratchet (Steels 1045 to 1020) heavy spot welding; welded assemblies per hour, 200

Fig. 27, Job 7—Rig hanger–ten projection welds (Steels 1035–40–45); welded assemblies per hour, 175

Fig. 28, Bar chart–production per hour on welded parts

In bar chart, Fig. 28, a comparison is shown of production welded assemblies per hour by the projection welded method and by the previous arc welding method. The production ratios for the seven jobs by the projection welded versus arc welded methods are as follows: Job 1, 3.7 to 1; Job 2, 10.4 to 1; Job 3, 6.2 to 1; Job 4, 6.5 to 1; Job 5, 5.5 to 1; Job 6, 4.6 to 1; Job 7, 7.6 to 1.

Recent production figures released show even greater differential ratios. In addition to high weld production per hour which is reflected in decided cost savings, there is a marked drop in welding man-hours required using projection welding. This is important in shop production planning.

The 463,000 welded assemblies arc welded required 17,350 welding man-hours while the same production projection welded was produced in 2770 welding man-hours.

Individual part costs, by both methods of welding, are not shown because average earnings and methods of figuring costs vary considerably among the various manufacturers. However, comparative production per hour figures are given and these facts can be evaluated on a basis of current costing methods.

High Lights of Production Projection Welding

1. Parts should be properly designed for projection welding.
2. Heavier sections than sheet steels can be welded.
3. Weld nugget sizes can be preset by design.
4. Steel shapes of irregular geometry can be successfully welded.
5. Welds (one or several) can be made at once.

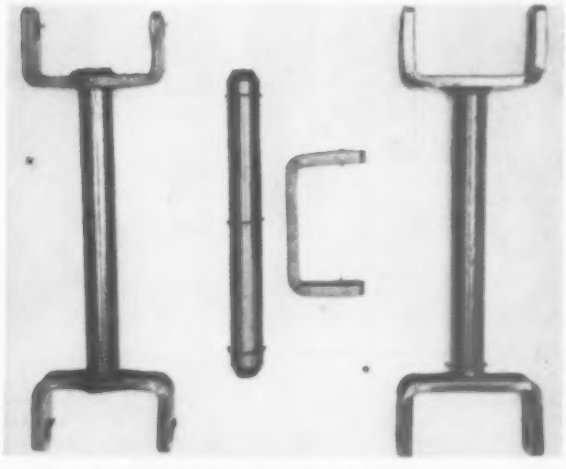


Fig. 21 Part 1—frame connecting bar

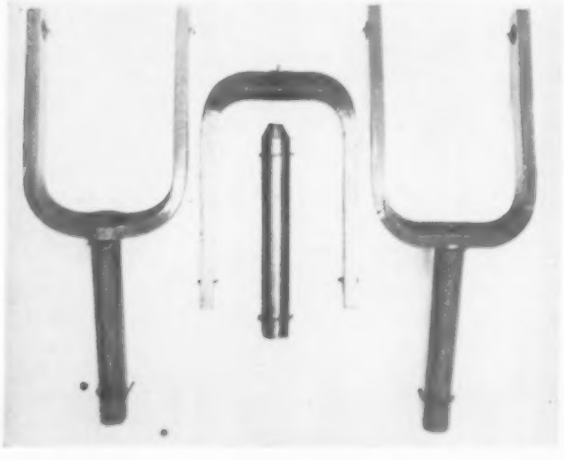


Fig. 22 Part 2—gage wheel yoke

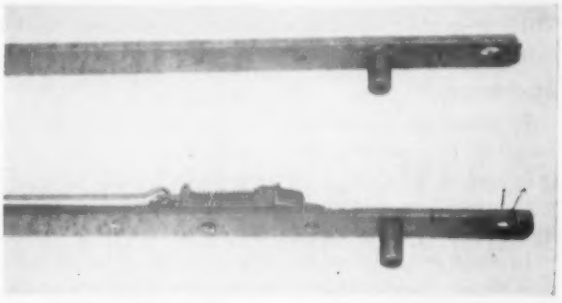


Fig. 25 Part 5—lever

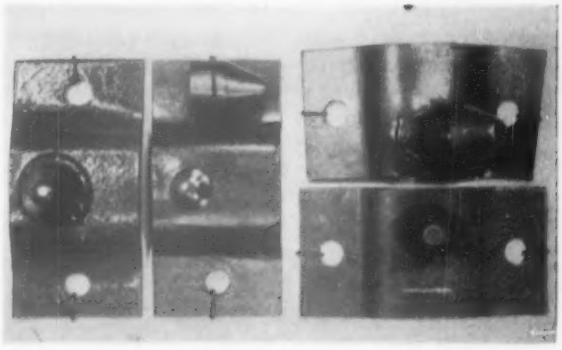


Fig. 23 Part 3—adapter

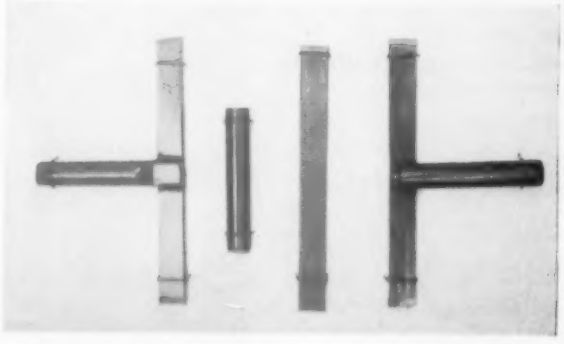


Fig. 24 Part 4—stub beam

6. Welds can be spaced closer (with no shunting) as compared to spot welding.

7. Using proper selection and location of projections, heat balance can be obtained between dissimilar sections.

8. To justify high capital outlay for welding equipment, jobs should be high production items—10,000 to 100,000 or more parts per year.

9. Scale-free and clean steels should be used.

10. Well-engineered welding dies are required.

11. Quality control should be used to deliver uniform dimensioned parts to welders. Weld quality should be checked by occasional destructive tests.

12. Welds of good strength are reproducible.

13. Welding schedules should be properly set up and no deviations allowed unless authorized.

14. Good on-the-job supervision and inspection are necessary.

15. General appearance of weldments is excellent.

16. Increased welding production at low cost can be attained by the use of projection welding.

Summary

By examples, an attempt has been made to point out some of the advantages of projection welding as a production tool. The picture given is perhaps just a glimpse of projection welding and some of its possibilities.

In most shop operations, it pays to stop periodically and "take stock"; that is, re-examine shop operations in the light of new process methods.

Material and labor costs are high today and probably will be no lower. The best opportunity for lower costs therefore, is by using better processes and produce more units parts per hour. Projection welding, and other resistance welding processes, where they apply are definitely in that category.

Fig. 26 Part 6—ratchet

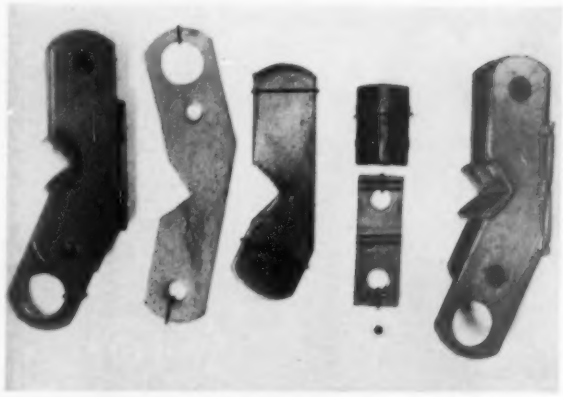


Fig. 27 Part 7—rig hanger

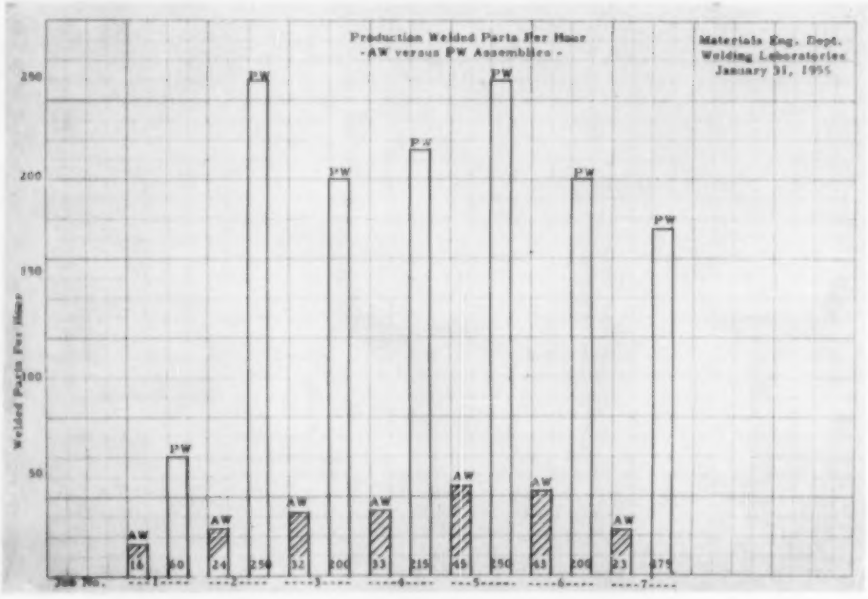


Fig. 28 Bar chart—Welding production/hr

Completing the final weld

THE GAMMA RADIOGRAPHIC CONTROL OF WELDED TRANSMISSION LINES

Some of the radiographic methods in operation in the United Kingdom for the inspection of welded pipe lines are reviewed by the author, as well as the relative merits of using radioisotopes coupled with a system of welding control

BY C. C. BATES

SYNOPSIS. The increasing and successful application of iridium 192 radioactive sources together with a system of welding supervision in the United Kingdom is recounted. The desirability of coordinating this nondestructive inspection tool with an over-all welding control is discussed and the author records the reasons for the system of control employed and reviews the advantages and disadvantages of gamma radiography under the field or site conditions existing. The selection and training of site inspectors and the apparatus used together with safety precautions are also examined. Reference is also made to ultrasonic examination in the field of gas transmission lines.

Introduction

The purpose of this paper is to review some of the methods in operation in the United Kingdom, for the inspectional control of welded pipe lines and to review the relative merits of using radioisotopes coupled with a system of welding control.

The increased availability of medium strength radioisotopes of gamma rays from the atomic piles has resulted in the wider use of this method of industrial radiography over other methods of semi- and nondestructive examination. In many cases radioisotopes have been used where, from a purely academic and technical point of view, they were not the most satisfactory method of nondestructive testing; but from a general convenience, control method and economic consideration, their academic disadvantages are more than offset by their practical considerations and results they achieve. The economic consideration arising from such things as site conditions and the wide disparity between the capital costs of a radioisotope complete with its "isotainer" and say an X-ray unit has done much to encourage their use.

It might be mentioned here that even iridium 192 isotopes are not scientifically suitable for the thin-walled high-tensile pipe lines which are beginning to be used to such a large extent nowadays, but it is considered

C. C. Bates is Chief Welding Engineer, Welding Supervision Ltd., London, England.

Presented at 1955 AWS National Fall Meeting in Philadelphia, Pa., October 17–21.

that they do show many practical advantages and with adequate control of welding, correct techniques for exposure, developing and interpretation, they are capable of achieving the desired results.

It will be appreciated that any fabricated structure such as an oil or gas transmission pipe line whose failure might involve serious damage or loss of life must be considered worthy of some expenditure, either by the client or the contractor in endeavoring to prove that the structure is sound so far as can be usefully and economically devised.

While many authoritative and useful papers have already been published on the subject of radioisotopes, it is not the intention to review or wish to reopen the well-discussed and controversial subject of gamma radiography versus X-radiography or trepanning; rather, to place on record some of the results of some years' application and achievement.

While it may be argued that gamma radiography, or, for that matter, X-radiography or ultrasonics, do not show all the defects, it is the author's opinion that the degree of defect definition obtainable together with the correct interpretation of the gamma graphs is of a higher control standard than that covered by some of the existing specifications, wherein only visual inspection and trepanning are specified. To this fact must be added the psychological effect upon the welder who, knowing that any faulty welds can be seen, is more likely to produce sound welds. It is hoped to show that this method of nondestructive radiography, coupled with welding supervision, is both an economical and practical proposition.

History

The inception of pipe-line inspection is lost in antiquity and probably goes back to the Romans with their wood, stone and clay pipe lines. Fabricated or welded iron and steel pipe lines are definitely a twentieth century innovation and, as far as can be found, the honor goes to the USA who produced one earlier than 1918.

The use of isotopes to aid inspection is more recent again, but as early as 1925, radium was used for industrial radiographic purposes,[1] and in 1944 radium was used in the Arabian desert[2] to control the standard of welding on an oil pipe line. According to Jefferson,[3] iridium sources were first made available for industrial radiography in 1949, and it is felt that such sources were probably used for pipe-line welding inspection in that year or early in 1950. The first artificial sources available in Great Britain for industrial radiographic purposes were cobalt 60 and tantalum 182.

Lines laid to date have mostly been of the mild steel heavier walled type such as is covered by API.5L, but more recently the thin-walled high tensile type of pipes are being produced and installed for oil transmission pipe lines.

It is the author's opinion that, though the total mileage of pipe lines in the UK is small compared with the USA, there are strong indications that there will be a slow but steady increase over the next decade.

Specifications

Pipe lines generally fall into two categories:

1. Oil or gas transmission lines which do not pass through or into built-up areas or refineries.
2. Lines which lie in built-up areas and on refineries, the latter including refinery service lines.

Although there is little difference in the inspection standard between these two types of lines, because of the importance of the areas in which they are laid, transmission lines in built-up areas must have a high joint efficiency factor and, accordingly, no relaxation from the specification standard can be permitted.

In general it could be said that the standard of weld acceptance in the UK tends to be higher than that given in the API or ASME codes—the higher industrialization per square mile in the UK will probably account for this tightening of standards.

While new specifications for pipe lines are at present being compiled in the UK, and indeed many of the larger companies have their own standards, the majority of lines already laid in the UK to date have been fabricated to composite specifications, mostly based on ASA.B.31.1, API.5L, 5LX and API.1104 (tentative). This latter specification has been found by the author to compare very favorably with one already used by him and he feels that this specification is the most advanced to date with regard to the employment of radiography as an inspection tool; also, it is regretted that nondestructive testing is not made mandatory.

Although a considerable amount of prefabrication is used on pipe lines, by far the largest amount of welding is done on site in the fixed position. This necessitates a highly skilled operator and indeed in some welding quarters it is considered that the approval pipe tests for welders are the most difficult that any welder can perform.

Since the welding on site has to be carried out in many different positions, the welder is tested accordingly. It might also be recorded that the competency tests in welding vary with the type of material involved and the wall thickness. The test to be performed by the operator generally consists of two 6-in. nipples of the same type of pipe on which he will be required to work along the line. After these have been welded, using the same techniques, current and electrodes as have previously been agreed, the specimen is cut and tensile and bend tests carried out.

Isotopes

Radioactive materials fall into two basic groups:

1. Natural sources such as radium, radon, thorium and uranium.
2. Artificial radioactive substances such as iridium, cobalt, tantalum, thulium, europium, cesium, etc.

The former substances having gained their radioactivity by bombardment of a stream of neutrons in an atomic pile, the radiation is, of course, electromagnetic.

Every isotope has its own characteristic wave length

Table 1—The Approximate Properties of Some Radioisotopes

Gamma-ray source	*Main lines in spectrum, (MeV)*	*Radiation unshielded one meter range, mR/Hr/mC*	*Half-life*	*Half value thickness in lead*	*Comparable X-ray kilovoltage*	*Approx. cost 4 x 4 m/m source at 2 C*	*Average metal thicknesses for which they are appropriate*
Cobalt 60	1.17, 1.331	1.35	5.3 yr	0.51 in.	1000/2000	£42 $117.60	2- to 6-in. steel
Tantalum 182	0.15, 0.22, 1.13, 1.22 (complex)	0.605	112 days	0.5 in.	1000/1800	£24 $67	2- to 6-in. steel
Iridium 192	0.13, 0.29, 0.58, 0.60, 0.61	0.27	74 days	0.11 in.	500	£5* + £10 $14 + $28	$^1/_2$- to $2^1/_2$-in. steel
Cesium 137	0.667	0.035	33 yr	0.24 in.	700	£200 $560	1- to 4-in. steel
Thulium 170	0.084	<0.0004	129 days	1-in. lead is adequate protection	120	£20 } 500 mC $56 } source	$^1/_{16}$- to $^1/_2$-in. aluminum

* Initial cost of source.

of radiation and as the penetrative power of the gamma rays is dependent upon the wave length; the greater the penetration—the shorter the wave length.

All radioactive substances decay according to a simple exponential law. Their rate of decay is often measured by their half-life—the time it takes for half the atoms to disintegrate. Obviously, as the atoms disintegrate, so will the gamma-ray activity fall; this means that after a certain period of time the gamma-ray activity is half of its original strength; the approximate properties of some radioisotopes are summarized in Table 1.

The chief merits of gamma-ray sources are:

1. Their small size.
2. The independence from main service supplies such as electricity or water.
3. Their relatively low cost compared with X-ray units.
4. The high penetration of radiation relative to industrial X-ray units in common use.
5. The lower image contrast which permits a large range of metal thicknesses to be recorded at one exposure on one film (relative to readily available X-ray units).

However, in radiographing specimens of relatively uniform thickness such as pipe butt welds, this low contrast merit may be objectionable because it operates against the optimum conditions for fault detection.

Artificial radioisotopes in Great Britain, of which about 1500–2000 sources are in use weekly, are commercially available as cylinders of 2, 4 and 6 mm diameter. A standard cesium 137 source holder which is very similar to an iridium 192 source holder is shown in Fig. 1.

There are three major factors to consider when selecting a radioisotope; these are:

1. Half-life period.
2. Gamma-ray energy.
3. Material to be radiographed.

On most oil and gas transmission pipe lines, the thickness of materials which one is required to radiograph is never over $1^1/_2$ in.; so, the most suitable isotope to use, as will be seen from Table 1, is iridium 192 or cesium 137, i.e., a low energy gamma source.

Cesium

It is perhaps interesting to record that this promising radioisotope (like strontium 90) was produced as the result of considerable research. As the result of separation, this useful and not fully developed source may eventually become a very valuable by-product instead of being a possible embarrassment to the Atomic Energy Authority as a form of radioactive sludge and waste.

Cesium 137 which has a half-life of about 33 years, and of which only limited quantities are available at this stage, is making greater inroads into the medical rather than the industrial field, although this position will no doubt rapidly change.

It has been reported that in the foreseeable future stocks as much as one ton or the equivalent of many thousands of radioisotopes may be available to mankind at large.

Gamma Radiography

Since radiography is essentially the casting of shadows, the physical dimensions of the source are an important factor in the sharpness of the radiographic image. A small source of radiation means a sharp image, or good definition; consequently, the source has either to be of small linear dimensions or be placed at a greater distance, to achieve the image definition required. Increased distance, however, means a greatly increased exposure time. With the artificially produced radioisotopes, they allow shorter distances between source and film than had previously been the case with radium. This not only reduces the exposure time but also enables exposures to be made in very restricted spaces and radiographs of reasonable definition obtained.

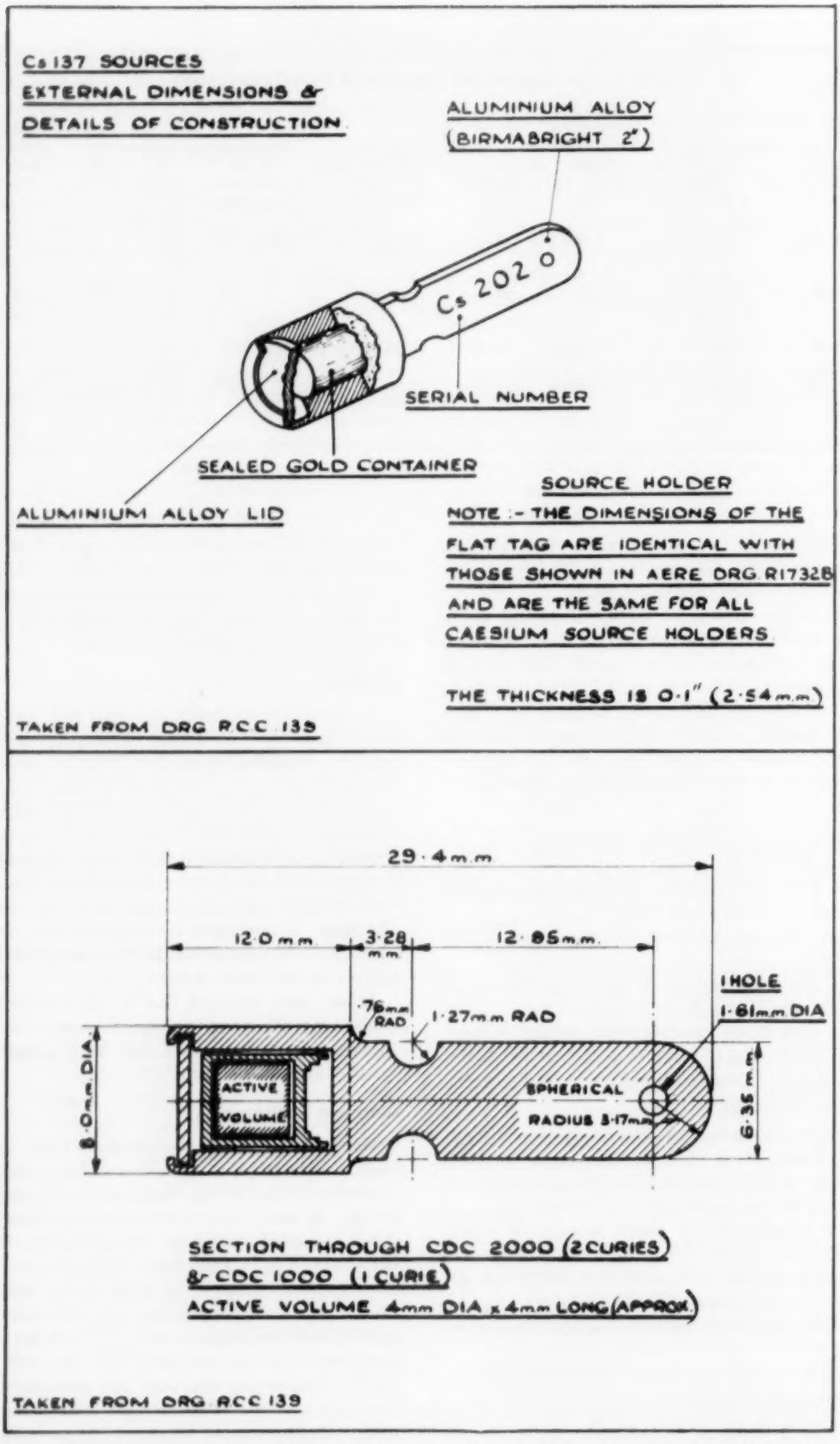


Fig. 1 Sketch of standard radioisotopes cesium 137 source holder. (Courtesy of UKAEA, Radio-Chemical Centre Amersham)

Definition is not the only criterion of radiographic quality; image contrast, or the tone difference in the image between a defect and the sound metal around it, is equally important. Iridium 192 has radiation which is much more easily absorbed and is consequently capable of producing radiographs with a much higher image contrast than those resulting from the use of any of the other radioisotopes commercially available today.

Films for Gamma-Radiography

Despite the difference in the quality of radiation from X-ray and gamma-ray sources, the same types of films and intensifying screens can be used, and these fall into main groups namely:

1. The so-called "screen type" films which are intended primarily for use with salt (calcium tungstate) intensifying screens.
2. The "nonscreen" type films which may be exposed either without screens, or between lead intensifying screens. The latter are used for almost all gamma-ray exposures.

The "nonscreen" type films are available generally in three speeds—fast, medium and slow—the grain being finest for the slow film. The fine-grain film is, therefore, recommended for all work requiring the detection of fine details. The fast type film is six times or more faster than the fine-grain type, but the grain may interfere with interpretation when fine defects are involved.

The relatively low contrast available with the higher energy gamma-ray sources tends to favor the use of fine-grain high-contrast films with lead intensifying screens, which not only intensify but also minimize the effects of scattered radiation. This film-screen combination provides the best conditions for fault detection. Where the exposure time can be reduced to a minimum, and providing the fault detection is adequate, the fastest type of nonscreen film could be used; but unfortunately in many quarters there is a tendency to rate exposure speed as the most important factor, without realizing the loss in fault detection which results. In the author's view, under general field conditions, medium speed films have been standardized upon to gain the maximum advantages from both speed and defect definition.

The interpretation of gamma radiography on pipe work, as with other work, is similar to that of X-radiographs, but the following points should be borne in mind. With gamma rays, the resultant exposures are somewhat less sensitive than those of the X-ray method, but a sensitivity of between 1 and 2% is normally obtained. A lower image contrast is also obtained, but here again this lower image contrast is readily counteracted by the competency of interpretation and it is always advocated that when interpreting gamma radiographs the size of the source and source to film distance should always be known.

In pipe weld radiography, the effective or diagnostic length of a radiograph is a function of the source to film distance–pipe diameter ratio (SFD/P.DIA.), and while the total film area can be reduced by using narrower films, it has been found that greater accuracy required in setting up under field conditions necessitates long setting-up times and does not always justify the film cost saving. Consequently it has been found to be of advantage to stock and use standard size films 15 × 4 in., as laid down in B.S.1443.

It will be evident, therefore, that the choice of films, screens and exposure factors is a matter calling for great experience in balancing the effects of the many factors involved.

Radiographic Techniques

Radiography on pipe lines can be effected in three ways: there is the single-wall technique—here, the source is inserted inside the pipe and a chain of films is placed round the welded seam. The practicability of this single-wall technique depends not only upon the wall thickness and internal bore, but also the possibility of introducing the source into the pipe itself. It is the author's opinion that this method, while completely radiographing the entire joint, has severe limitations and is not always practicable with the diameter to wall thickness ratio, this ratio having been practically set at a source to film distance of $18t$, where t is the wall thickness.

A second method, seen in Fig. 2, is termed the double-wall technique; the welding is examined in sections, the film being placed on only a portion of the joint at a time, the new film and source being moved around to the next appropriate position. This technique is normally employed on pipe lines fabricated by the stove pipe method, as it is possible to keep the film to source distance to a minimum, consequently reducing expo-

Fig. 2 Gamma radiography of pipe butt weld using double wall technique. Note source extracted from isotainer

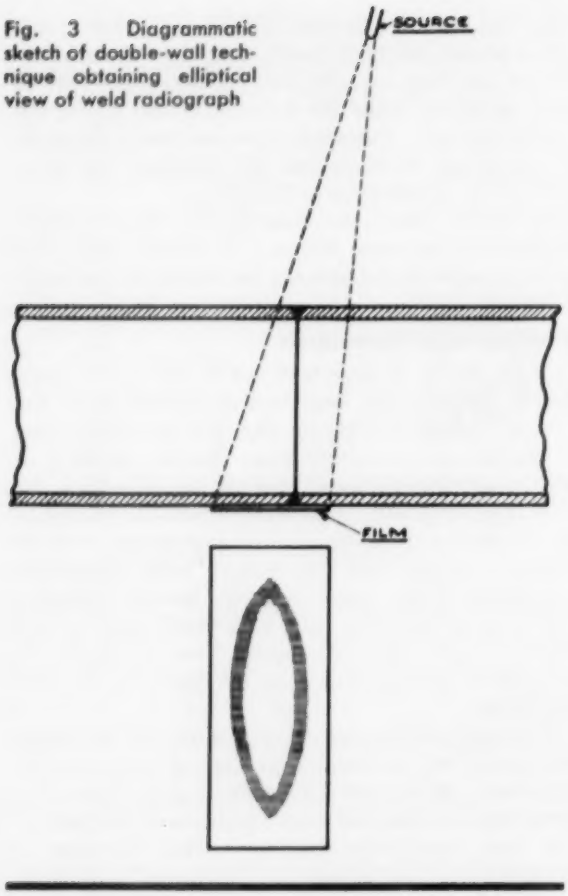


Fig. 3 Diagrammatic sketch of double-wall technique obtaining elliptical view of weld radiograph

sure time—the source being placed in close proximity to the opposite side of the pipe to the film.

The third technique, shown in Fig. 3, is also the double-wall technique; here the source is positioned some way from the pipe so that both the top and bottom of the weld are produced on one film; but, due to having to move the source some distance away from the pipe, the resultant exposure time is seriously lengthened, so that while one film is exposed and developed per joint the advantage is readily offset by the increased exposure time. This method is sometimes used with X-radiography and is not always practical with gamma radiography.

Transport of Radioisotopes

The handling and transport of isotopes could present a serious problem; however, as with nearly all other aspects of this method of radiographic and welding supervision, the maximum measure of standardization has been instituted. New sources from the atomic pile are transported by rail, road or air—according to the distance from the pile to the nearest large town, airport or railway station. As transport costs are relatively cheap, and as the UKAEA (Isotope Division) is most efficient and cooperative, it has been found that it is best to leave the initial transport of new or reirradiated sources to them. After receipt of the sources, either at the head office or the field base where a transfer of old sources takes place, the sources are always moved by the field inspector's site transport.

As will be seen from Fig. 4, the source in its container is carried at the furthest point from the driver and secured in some simple way so as not to open and give the inspector a dose of radiation. Due to the arduous conditions met on pipe lines and in field work, the author uses a heavier type of "isotainer" than one which might normally be used with 5C. iridium sources. Although this has caused some slight discomfort to the inspector who has to carry it, it has been proved that this type of isotainer has justified its use in a reduced average weekly dosage of radiation. Though it is not a legal requirement, when isotopes are being transported by the author's staff, warning notices are always carried in a prominent position at the front and rear of the vehicles as a safeguard in the event of an accident and the driver becoming incapacitated; a specimen notice is shown in Fig. 5.

Site Conditions

The site conditions encountered when inspecting

Fig. 4 "Isotainer" secured and ready for field transport

Fig. 5 Specimen radioisotope transport warning notice

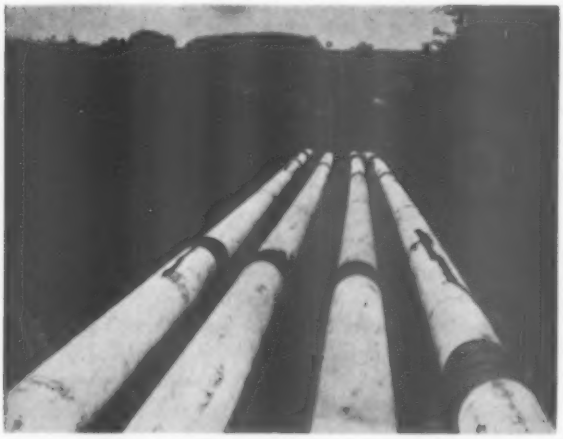


Fig. 6 Multiple pipe line tract after radiographic examination

Fig. 7 Field inspector arranging weld and joint identification marks on cassette

transmission pipe lines are a very serious factor when operating an over-all welding and radiographic control service. In places, transmission pipe lines traverse isolated country and to add to these conditions much excavation and overburden removal has to be met with and overcome. In addition, "rights of way" are invariably well ploughed up by the contractor's heavy pipe-laying and stringing plant, before the radiographic unit moves up.

While it is appreciated that the site conditions in the UK are probably no worse than conditions encountered say in the USA, and mileages involved are smaller, it is considered that due to the greater building density per square mile and the more rapid change of ground contour, the equipment and the operating systems in the UK have to be more flexible and adaptable.

A typical—although not necessarily difficult site condition—is shown in Fig. 6, where the inspector had to drive over muddy fields from the nearest road before he even neared the site of his inspection, and then he had to clamber down into a trench up to 10–20 ft deep. Thus, it will be seen that, while the X-radiography could be used if power were available on site, considerable handling time would be involved before one radiograph could be taken.

As mentioned earlier, the type, size and weight of the inspection equipment must be seriously borne in mind and it might be interesting to note the portability of the ancillary field equipment shown in Fig. 7.

Site Personnel

In the organization under discussion, the staff are required to be or are trained to become competent welding engineers, after which they are instructed and trained in the use and handling of isotopes and gamma radiography, thus becoming welding engineer/radiographers. It has been found that under this system the site engineer can, on finding defects, advise the resident engineer and the welding operator not only what they are, but how and why they are caused. Thus, being able to talk practically to the welding operator has not only improved the standard of welding but also assists in keeping the percentage of radiography to a minimum.

It is also the practice to encourage the welder to see and learn about the results of the examination of his own welds. This type of welding engineer/radiographer does not exist in industry and it is considered that it takes approximately four years to get such an engineer to that state where he can control his own site project.

Not only is it necessary to have inspection standards for construction, but it is necessary to have uniformity in the inspection organization itself and, accordingly, standing instructions on radiographic work have been introduced. These standing instructions not only specify how the radiography will be applied and undertaken, but also the exposure times for standard radiographs, joint and weld identification, definition and density. A typical exposure chart is shown in Fig. 8, in which source strengths against exposure time, source/film distance and thickness are given. In Fig. 9, a specimen source/strength half-life chart issued with each radioisotope by the UKAEA is shown.

Site Laboratories

As will be appreciated from earlier remarks, one of the major factors in operating an efficient system of welding supervision is the "base of operations" and the speed upon which the results of tests or radiographs can be produced. In general, there are four types of operational base:

(*a*) Self-contained and motorized mobile laboratories.
(*b*) Self-contained, motorized and semi-articulated mobile laboratories.
(*c*) Self-contained and towable mobile laboratories.
(*d*) Semi-permanent and nonmobile laboratories.

Naturally, the nature of the project and the justifiable expenditure govern the type of laboratory that can be used. Coupled with these two factors is the question of the site conditions that might be encountered. The basic design of each unit is essentially the same; it is comprised of a workshop/office in one section and a darkroom in the other section. Each of the types mentioned have their relative merits and disadvantages and these are briefly mentioned below.

In the case of laboratories (a) and (b) above, these may be mounted on a two or four-wheel drive chassis and are more suited to sites demanding maximum mobility, such as fast moving pipeliners who may fabricate up to three miles per day. If either of these types of vehicle have to negotiate boggy or hilly country, difficulty may be experienced unless adequate motive power is available. This can be a major disadvantage as, if powerful engines are installed, it means tying up a powerful and expensive traction unit while the mobile laboratory is temporarily static. Being of a larger nature, these types of units can be entirely self-contained and capable of generating electricity for darkroom purposes and auxiliary tools, and also carry a reasonably adequate water supply fitted with filtration unit. It has also been possible to install refrigerant and air-conditioned plant for operation in tropical regions. Either type (*a*) or (*b*) may cost anything from $4000 upward, depending upon the equipment installed.

From experience of operating the towable units mentioned in (*c*) above, the writer considers that this type of mobile laboratory has many advantages. It has been found satisfactory for this type of unit to be based at the pipe-line contractor's depot and to move when the pipe-line contractor moves his operational base. This type of unit is capable of being towed by a landrover/-jeep type of transport allocated to the site inspector. Although the unit has adequate water carrying capacity in the form of two tanks—one upper and one lower, being attached to the site base, it is possible to connect up to both the local mains for water and electricity. A duplicate electrical system is installed so that the unit can operate from heavy duty storage batteries. One of

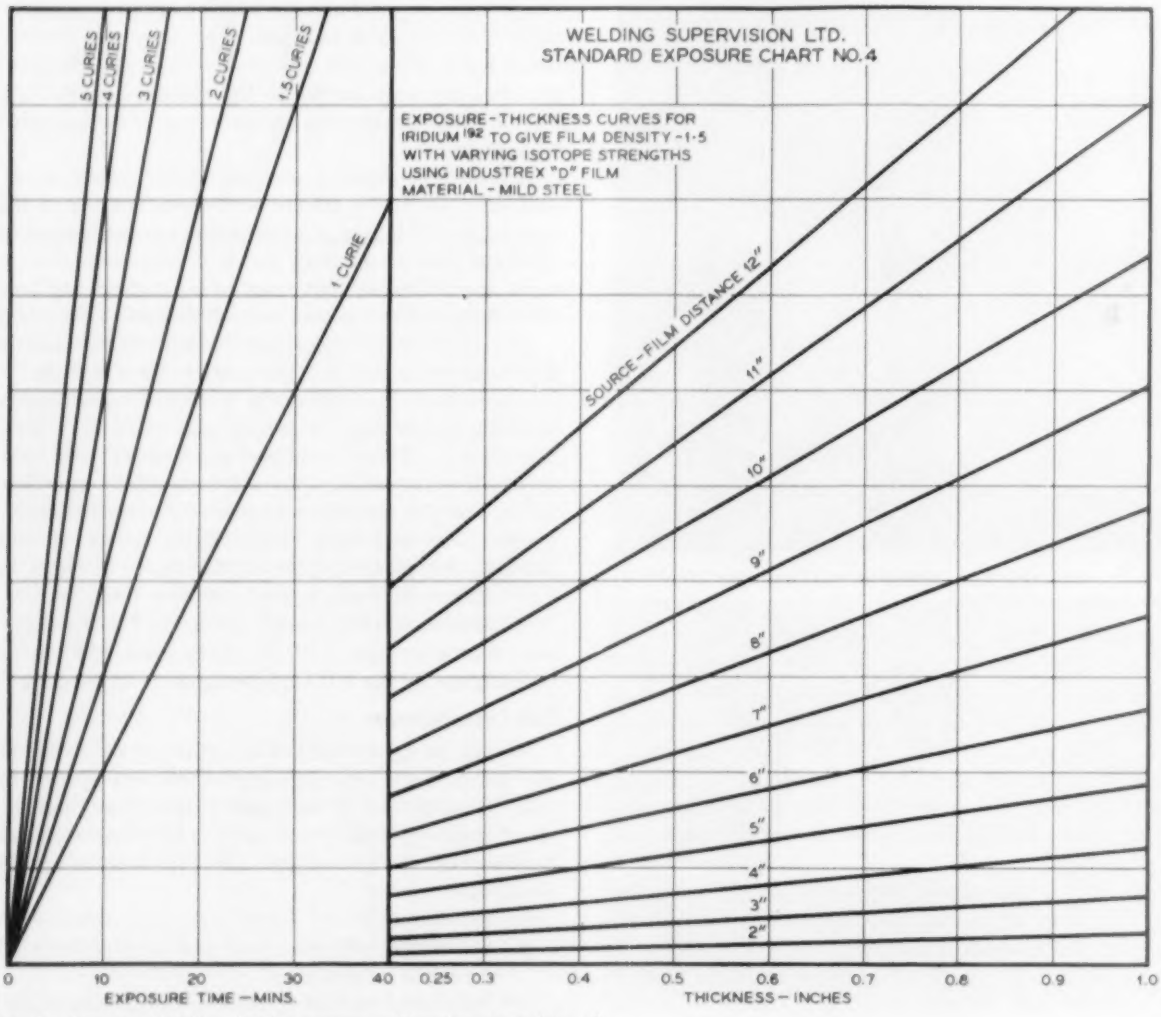


Fig. 8 Standard iridium 192 exposure calibration chart (No. 4)

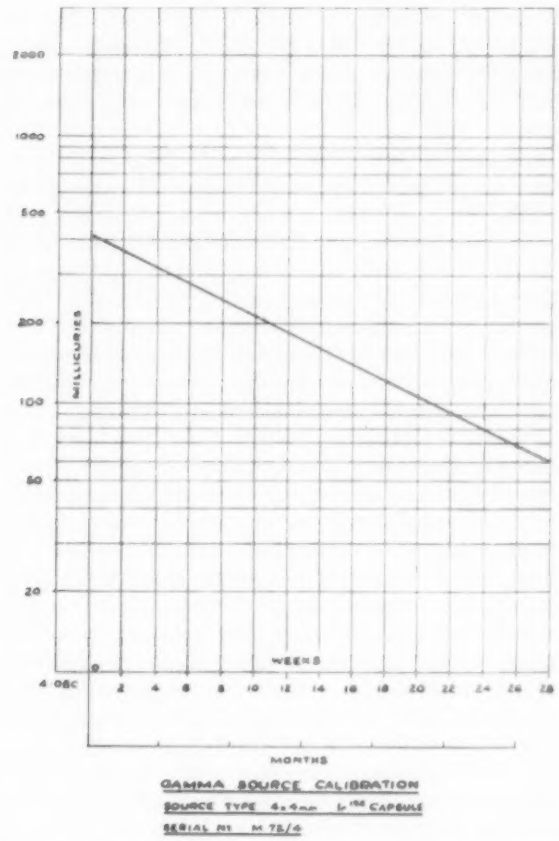


Fig. 9 Specimen iridium 192 source/half-life chart (Courtesy of UKAEA, Isotope Division)

the disadvantages in this type of unit is its short life due to its light construction which may suffer considerable damage when being towed over difficult site conditions. A specimen of this type of laboratory is shown in Fig. 10 together with its tug unit, illustrating that this type of mobile laboratory is capable of traversing along the normal "right of ways."

In the case of the fourth laboratory, this (*d*) type is generally used in built-up areas where movement of the pipe-line contractor is not rapid and the distances involved are comparatively small. It generally consists of a standard sectional hut and again is subdivided into two portions, one to form the office/workshop and the latter part to form a darkroom. Being used mostly on large sites or in built-up areas, this type of unit takes supplies of water and electricity from the mains. This type of laboratory—although listed as nonmobile—can readily be taken down, moved and re-erected on a fresh site and the electrical connections are so arranged that in desectionalizing, simple connections only have to be broken. One difficulty that is experienced with the transporting of this type of unit is the maintenance of adequate blackout requirements for the darkroom portion.

Welding Control Systems

While there are successful pipe-line inspection systems operating with both independent welding engineers and radiographers, the one operated by the author and proved to be highly successful is a merger of these two functions into one. Very briefly, this welding supervision system operates as follows:

When the construction of a pipe line is scheduled, a member of the staff is assigned as project engineer to review the construction and working conditions and to obtain other data which may be relevant with the client's engineer. In the light of information obtained, standard welding specifications are suggested, but where no applicable specification exists, an existing one is modified or a new one compiled; this is then written

Fig. 10 A towable mobile laboratory on a pipe line "right of way"

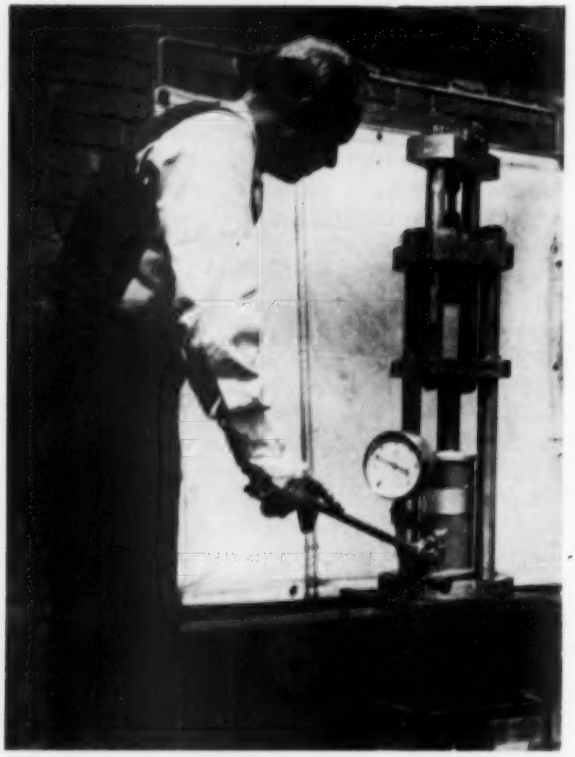


Fig. 11 Portable tensile and bend test machine for site testing of welders

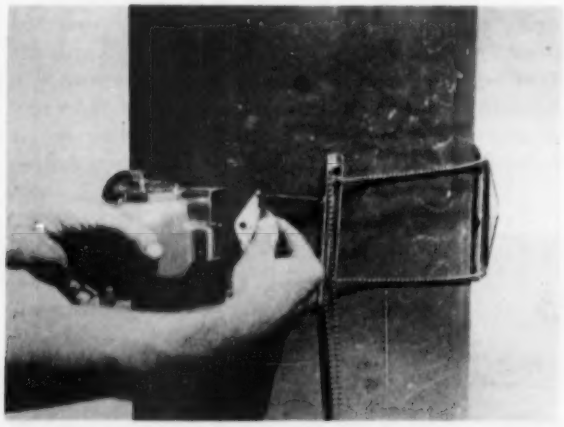


Fig. 12 Gamma-radiography with a specially designed pipe line isotainer (Courtesy of Gamma Rays Ltd)

into the over-all pipe-line specification. After the contractor's proposed welding procedures have been vetted, the procedure confirmation tests are witnessed by the project engineer and the necessary test certificates are issued. This procedure test is conducted by the contractor's personnel at either the radiographer's welding laboratories or at the contractor's depot.

After planning and requisitioning the necessary inspection equipment and setting up a field base, all welders are tested for competency before they are allowed to work on the line. Welder approval tests similar to those laid down in API.1104 are generally applied, and, after proof of the welder's competency, a certificate is issued to both the engineer and the contractor.

In Fig. 11 a portable testing machine is shown: this bend and tensile machine which is installed in one of the mobile site laboratories, is capable of effecting reduced section tensile tests up to 15-ton (33,000-lb) direct load, nick-break tests and face and root bend tests. Although yield, reduced area and elongation tests can be performed, such tests are used for guidance purposes.

As the majority of defects found in pipe welds occur in the early stages of welding (i.e., the root run and hot pass), considerable attention is paid to fit-up and the root run on site, and after the completed joints are finished a percentage of radiography is applied. These percentages may vary from 100% down to 10 or 20%, but it has been found by practice that these should never be allowed to drop below 5%.

As the over-all staffing of a project depends to a considerable extent on the size of the project and the contractor's method of construction, no exact staffing figures can be quoted. On slowly constructed pipe lines, probably only one or two welding engineers are employed; in the case of larger projects eight, ten or twelve men may be engaged, depending upon the number of main spreads operating. On a recent project when 5–6 miles of line were being welded per week the following staff was employed:

(*a*) One engineer was employed at the front end, supervising and visually inspecting joint alignment, root (stringer bead) and second run (hot pass) welding: any unsatisfactory joints being removed immediately and any doubtful joints being marked for the second engineer.

(*b*) A second engineer, who was equipped with two radioisotopes, was at the back of the "main spread" effecting final visual inspection of all joints and radiographing a percentage of joints including the doubtful ones marked by the front end engineer. While one exposure was being taken the second source was being set up for the next exposure.

(*c*) A third engineer, who was responsible for loading, unloading and developing films, also effected radiography and visual inspection of the tie-ins and crossovers which are inspected 100%.

(*d*) The project engineer, besides effecting an overall supervision and maintenance of records, was responsible for the interpretation of all gamma graphs, urgently required results being sent to the pipe-line inspectors over the field radio communication system.

As has been mentioned, the double-wall technique is used mostly and two variations of this are illustrated. In Fig. 2 the source is shown removed from the "isotainer" and inserted in a lead sheathed locating block, which not only correctly locates the source but also positions and retains the film cassette. This type of setup has functioned very satisfactorily in awkward bell-holes and lines where the pipe may be partially

submerged in a water-logged trench. In Fig. 12 a specially designed "isotainer" curved to fit the pipe, and which was used on the Pakistan Natural Gas Pipeline, is attached to a circumferential locating and film-retaining band.

It might be recorded that coating inspection, pressure testing and leak detection inspection operations have also been incorporated into this welding supervision service to form an integrated inspection team.

Welding Techniques

The actual welding procedure employed will vary as the result of the local circumstances but, in general, in the case of the steel pipe lines, there are four basic techniques which can be adopted for either butt or spigot and socket fillet-welded joints.

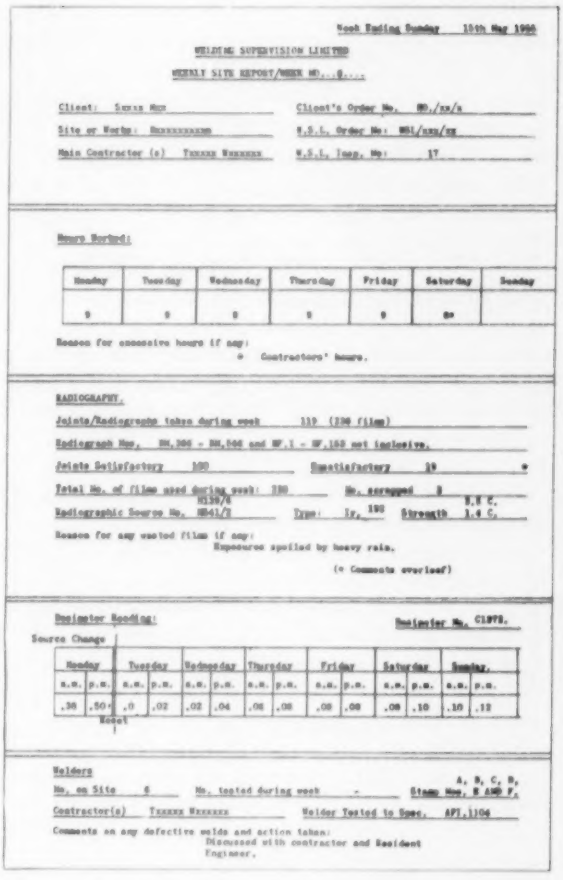
In the case of the vertical upward method where welding starts from the 6 o'clock position and proceeds to the 12 o'clock position, it can generally be considered that a smaller number of heavier runs are employed and a considerable amount of more latitude in the joint fit-up is permitted; and this technique can also readily be employed in tie-in or bell-hole welds. Furthermore, both BS.1719, Group E110P (E6010) cellulosic and E317 (E6013) rutile types of covered electrodes can be employed. One of the points to watch with this technique is over or under-penetration of the root bead depending upon the operator and joint alignment.

With roll welding, two or more pipes are assembled on rollers and the operator welds the joint entirely in the flat position. Here again, both cellulosic and rutile covered electrodes can be readily employed. Because the weld is in the downhand position, it does not require the same degree of skill by the operator as required for positional welding. The obvious disadvantages of this method of fabrication are that it also necessitates position welding operators being employed on tie-in welds.

With the "C-J-B" technique, where cellulosic electrodes are mostly used, the root run is welded by the vertical upward technique and subsequent runs are welded by the vertical downward technique. This type of procedure has been employed with considerable success on tie-in welds and special crossings as greater latitude is permitted on the joint fit-up. While the root run welding time is slower than the vertical downward method, the total welding time for the complete joint is approximately 50% of that required by the vertical upward procedure.

As the result of assistance and cooperation with the American welding engineers, the vertical downward or stove-pipe technique is now firmly established in Great Britain. While this method of welding is exceedingly fast and satisfactory radiographic welds can be produced, its disadvantages are that a higher grade of welding operator is necessary and a higher degree of joint alignment and fit-up is required. A more stabilized type of welding plant is required and only cellulosic type of electrodes can be used.

With regard to the electrodes, it has generally been found that with the rutile type of electrode there is a



Week Ending Sunday 15th May 1955

WELDING SUPERVISION LIMITED

WEEKLY SITE REPORT/WEEK NO...9....

Client: Swiss Mon — Client's Order No. MO./xx/x

Site or Works: Hxxxxxxxxx — W.S.L. Order No: WSL/xxx/xx

Main Contractor (s) Txxxxx Wxxxxxx — W.S.L. Insp. No: 17

Hours Worked:

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
9	9	9	9	9	8*	

Reason for excessive hours if any:
* Contractors' hours.

RADIOGRAPHY.

Joints/Radiographs taken during week 110 (230 films)

Radiograph Nos. HS,306 - HS,506 and WF.1 - WF,160 not inclusive.

Joints Satisfactory 100 — Unsatisfactory 10 *

Total No. of films used during week: 230 — No. scrapped 8

Radiographic Source No. HS41/2 (HS307/6) — Type: Ir, 192 — Strength 1.4 C. (2.8 C.)

Reason for any wasted films if any:
Exposures spoiled by heavy rain.

(* Comments overleaf)

Dosimeter Reading: — Dosimeter No. C1972.

Source Change

Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday	
a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.
.38	.50	.0 Root	.02	.02	.04	.06	.08	.08	.08	.08	.10	.10	.12

Welders — A, B, C, D, Stamp Nos. E AND F.

No. on Site 6 — No. tested during week -

Contractor(s) Txxxxx Wxxxxxx — Welder Tested to Spec. API.1104

Comments on any defective welds and action taken:
Discussed with contractor and Resident Engineer.

Fig. 13 Reproduction of a weekly report used in connection with a site welding supervisory service

danger of slag entrapment in the toes of the weld, whereas with the cellulosic type there is always the risk of hydrogen entrapment due to the higher hydrogen content of the electrode. In the case of the vertical downward technique, this is partially eliminated due to the higher welding currents, subsequently, a larger molten pool and thinner layer of metal deposited per electrode run.

Records

Without the maintenance of some simplified and accurate system, the full benefits of visual and radiographic inspection cannot be gained, and considerable knowledge and data have been obtained through the use of the daily, weekly and map records employed. A reproduction of a specimen weekly site report form returned by each engineer is shown in Fig. 13. This form is returned to head office for administrative purposes. The specimen daily radiographic report illustrated in Fig. 14 indicates the necessity for the maintenance, increase or reduction of the radiographic percentage. This is returned to the client's engineer on site. The form shown in Fig. 15 is a weekly assessment return of any section of a pipe line and acts as a guide to the field and project welding engineers as to their efforts

Job No. xxx/56

WELDING SUPERVISION LIMITED.

RADIOGRAPHIC REPORT. No. XX

Site: [illegible]

Contractor: Cxxxxxx-Jxxx Bxxxx Limited. Date: 18th July 1956.

W.S.L. Supervisor: Mr. D. A. Gxxx.

Joint No.	Welder.	Dia. of Pipe.	Welding Position	Class of Joint	Remarks.
		12" Main Spread.			
991	FX.HJ.EA	12"	P	B	
992	"	"	P	C	
993	"	"	P	C	
994	"	"	P	C	
995	"	"	P	B	
996	"	"	P	C	
997	"	"	P	C	
998	"	"	P	B	
999	"	"	P	C	
940	B	"	P	B	Weld left incomplete - ASG Tie in.
		10" Spread			
1	HF.SJH.WH	10"	P	D	No penetration - to be cut out.
2	"	"	P	B	
3	"	"	P	B	
4	"	"	P	D	No penetration - to be cut out.
5	"	"	P	B	" " " " "
6	"	"	P	B	
7	"	"	P	C	
8	"	"	P	C	
9	"	"	P	C	Subject to Gouge 0-3".
10	"	"	P	C	
11	"	"	P	C	
12	"	"	P	C	
13	"	"	P	C	
14	"	"	P	B	
15	"	"	P	C	
16	"	"	P	C	

Welding standard has fallen.

Fig. 14 Specimen of a daily radiographic report form

PIPE WSL/3

Section WXXX GXX WXXX Week Ending 22nd May 1961.

Contractor Cxxxxxx Jxxx Bxxxx Limited (Contract xxx/xx).

SECTION IN WHICH WORK IS:

a) In progress 12" Main Spread Map Refs: Main Ordnance Survey.

b) completed Branch C, D and E. Map Refs: Strip L-M.

WELDS COMPLETED:

a) during week: 258

b) up to date: 1,700

VISUAL INSPECTION:

a) Welds accepted: 243

b) Welds rejected: NIL

c) Welds repaired: 2

TOTAL: 245 99%

RADIOGRAPHIC INSPECTION:

Joint Classification:

A - 11

B - 17

C - 11

D - 11

TOTAL EXAMINED - 50 20%

TOTAL ACCEPTED - 20

NO. OF QUALIFIED WELDERS: -

No. 9

WELDERS TESTED DURING WEEK:

NAME	THEY POSITION	RESULT	TEST'S STAMP	DATE
Catherwood	5 G	Passed	M	4-May 1956.
Harriott	5 G	Passed	M	5-May 1956.

SIGNED: D. A. Gxxx
Project Engineer.

Fig. 15 Weekly inspection and radiographic summary report

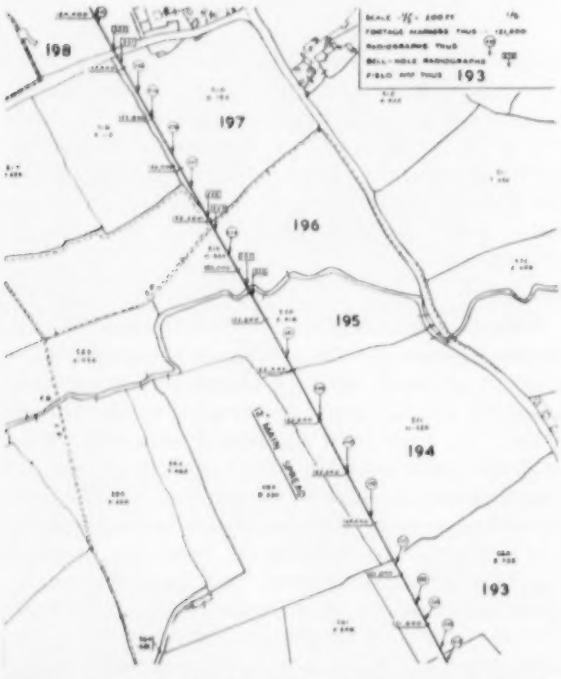


Fig. 16 Specimen pipe line and radiography location strip map

during any current or following week. This form is returned to head office, the contractor's engineer and the client's senior engineer. The subsection map illustrated in Fig. 16 records the location not only of the pipe line proper but also the radiographic number of each joint examined and whether it was initially accepted or rejected. Each radiograph records:

1. The welding engineer/radiographer's number.
2. The project or order number.
3. The section number or letter of the pipe line concerned.
4. The subsection number or field number and pipe diameter.
5. The joint number (and position welded in when necessary).
6. The contractor's identification initials.
7. The welder's identification number.
8. Linear markers.
9. Penetrameter (if necessary).

This recording is achieved quite rapidly with the aid of a specially developed and patented[10] cassette, and in Fig. 17, an engineer is seen removing this cassette from a joint. With the aid of the above records it will be seen that it is possible to supply the engineer operating the pipe line with a fairly comprehensive history of

Fig. 17 Radiographic cassette specially developed for pipe line weld inspection

every joint radiographically examined for his future reference.

Economics

It will be appreciated that the subject of welding inspection and gamma radiography could readily be the subject of two separate papers and while this is desirable it is not practical at this juncture; therefore it is only possible to briefly record a series of statements which have been found to operate with some consistency over a period of time.

The advantages and costs of welding control are probably viewed by the engineer and the accountant from different standpoints; it is therefore desirable that both these points of view should be as close together as possible. On one hand, the method of control should have sufficient coverage to ensure the engineer that the entire pipe line meets the minimum standard laid down by the engineer. On the other hand, the cost of the inspection should not be such as to make it financially undesirable.

It is not advocated that there should be nondestructive testing (or inspection) for nondestructive testing's sake. If a percentage of nondestructive testing is judiciously applied, this should effect an over-all measure of control and satisfy both the engineer and the accountant.

Further, it is considered that by only taking radiographs after the welds have been completed is like "closing a door after the horse has bolted" and serves no useful purpose.

As to the actual percentage of radiography, this will naturally vary with many factors; but as a general rule it has been found that in the initial stages 100% can be and is desirable. After a few days, as production speeds go up, and as a satisfactory standard has been achieved, this percentage can readily be dropped to 50% and when it is confirmed that the standard is still being maintained, this percentage of radiography can drop to 10% or even less: it is never advocated that this percentage should drop below 5%.

While the cost of the radioisotope, compared with say an X-ray plant, is very small it should always be considered that the auxiliary equipment, in both cases, excluding films and chemicals, will probably cost up to and over 300% of the cost of the radioactive source itself. Similarly the "write-off" values of all the equipment must be taken into serious consideration as an economic factor.

As has been mentioned earlier, standardization both in films, techniques and equipment is strongly recommended from a technical and economic standpoint. It might be recorded that in the author's organization even the life/strength and exposure time of the isotopes have been standardized as far as possible and very seldom is the radioisotope used below its half-life strength.

Encouragement and permission should be given to the site staff to develop auxiliary equipment to suit the particular needs of the respective project and, if as the result of this *ad hoc* development, more efficient methods of effecting the over-all service are found, the development should be incorporated into the standard equipment. On the other hand, auxiliary equipment and techniques developed for a specific job can readily be discarded at the end of a particular job without any heavy financial loss.

It will be appreciated that the type of personnel trained to effect both welding inspection and radiography, as the result of their dual skill, receive a higher rate of remuneration than that of a single-operation man; nevertheless, on both small and large projects it has been found that the over-all staffing required is less than with separate inspectors and radiographers, thus effecting not only a saving in manpower but also financially. In the initial training and refresher course tuition of site personnel many indirect costs will arise, as with other factors such as research and development, and these, if not evenly distributed, can seriously affect the over-all costs and economics of welding inspection and nondestructive testing.

While no hard and fast costs can be quoted, as these will vary with many factors mentioned earlier—as a very approximate guide it has been found that the costs of this welding inspection control are briefly as follows:

1. As percentage cost of line, excluding cost of pipe . . . max 3.5% avg 2%
2. As percentage cost of pipe . . max 2.5% avg 2%
3. As percentage cost of line including cost of pipe . . . . . max 1.6% avg 1%

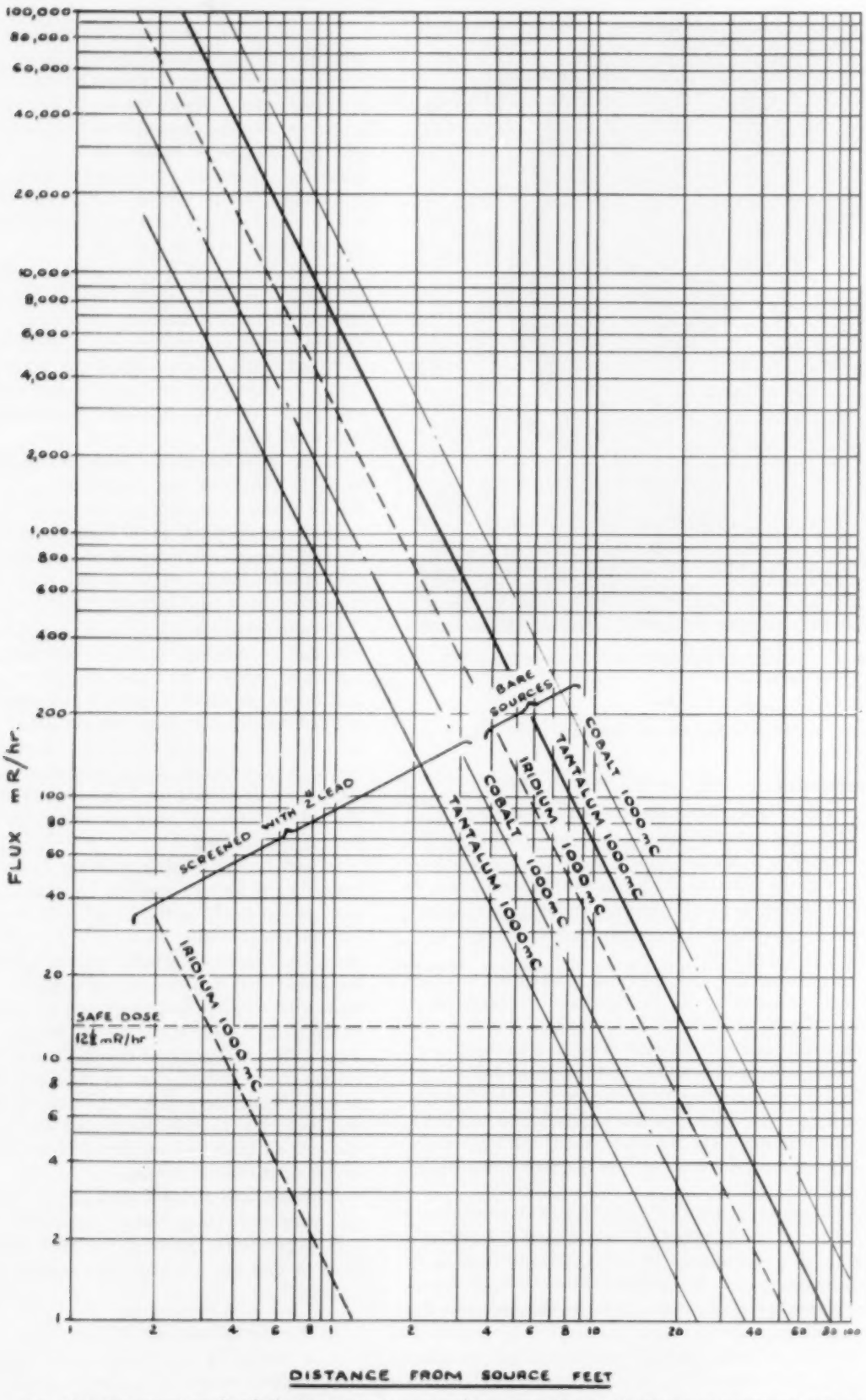


Fig. 18 Radiation flux (mR/Hr) off certain isotopes. (Courtesy of Dr. J. S. Blair and *Iron & Coal Trades Review*)

It is perhaps interesting to record that on one project recently completed where the over-all percentage of the joints radiographed, was 19.09%, the percent/footage of welding radiographed worked out at 29.52%; as the result of close and authoritative control the number of joints rejected was reduced from approximately 10 to 0.2%.

Health and Safety Precautions

Although radioactive sources themselves present no worse hazards than many other industrial substances, certain basic and essential precautions must always be taken.

Unlike X-rays, radioactive sources are always "alive" and it has been found that, while screening can and is employed, the best precaution that can always be adopted is the one of distance. Pocket dosimeters of the ionization chamber type are issued to all the staff, together with appropriate warning notices, and when actually setting up or undertaking radiography these dosimeters are attached to the wrist and the engineer records the reading both night and morning; this information is returned weekly to head office for scrutiny and inclusion on a large chart.

The storage of isotopes on sites is also a problem and a simple but effective arrangement that has proved satisfactory is a piece of piping sunk into the ground and the "isotainer" is lowered into it at the completion of each day's work. The depth of this pit is such that when the handle of the "isotainer" is removed it is impossible for an unauthorized person to lift it out. Additional notices are placed round the store, and the area is also roped off. Such precautions are adopted, as it will be appreciated, because all types of personnel are encountered and, accordingly, the safety precautions have to be rigidly enforced to protect the negligent individual from himself.

"Isotainers" are normally manufactured from two types of material, tungsten (density 16.5 g/cc) and lead (density 11.3 g/cc). Although the majority of containers available to industry are safe for carrying the isotope strengths listed on them, it should be borne in mind that these measurements are always taken on a 1-meter distance. Since operators are required to handle these "isotainers" at close distances in setting up and taking down, it is advocated that containers should be checked by a Geiger counter at the surface and at the handle to ascertain the maximum handling time.

While removal of any source from its container is not generally advocated, frequently sources have to be removed for an individual job. When such instances do arise, such as fast moving pipe lines, the source is removed and retained on its handling rod, which is at least 1 meter in length, and the source is not removed until the entire setup is completely ready.

In the author's organization, all staff members are subject to medical examination at periods not exceeding six months, and this medical report is compared with the man's chart of weekly dosages obtained. It might be interesting to record that the average weekly dosage received by all the staff over quite a long period has never exceeded 250 milliroentgens per week.

An additional precaution which is employed whenever sources are removed is the use of a monitor for ensuring that the permissible radiation is not exceeded and, what is more important, that the source is not lost or mislaid. A small source could be very easily lost in the mud, and until this source would be found great difficulty and inconvenience would be caused. Furthermore, this monitor can aid in determining the safety limits in laboratories or transporting radioactive materials. Radioactivity is both visible on the built-in meter and can be indicated audibly by connecting an earphone to the apparatus. In Fig. 18 the safe dose, based on 40 working hours per week, that is 500 milliroentgens, or 12½ milliroentgens per hour, is shown as a dotted line. The flux is given for a strength of one curie, the radiation from other sources being proportional to their strength.

Ultrasonic Examination

Early in 1954 an investigation[6] was undertaken to examine ultrasonically a 12-in. diam thin-walled butt-welded pipe line and to assess whether any advantage could be gained instead of using radioisotopes. As far as was known this was the first time field trials of any extent of this method of inspection had been carried out. Naturally, prior to the investigation, a certain amount of research was undertaken and preliminary tests were conducted with prepared and known standards of acceptance and rejection.

One of the initial problems that had to be overcome was the field power supply. After some trials this was achieved by using two 12-v 100 A/H heavy duty batteries coupled to ex. Air Force type 5U/111, 230 V. 50~ rotary converter. Fitted with the necessary isolation gear and 80-ft leads, all of this equipment was mounted in the back of a landrover as shown in Fig. 19.

With this type of mobility, it was possible to negotiate most of the "right of ways" and thus permitted the inspector to be right up behind the main welding squad.

Fig. 19 Ultrasonic field inspection equipment

Fig. 20 Ultrasonic inspection of a pipe butt weld under field conditions

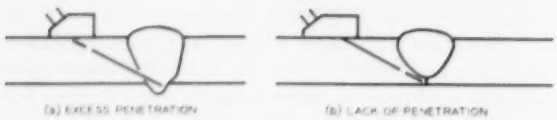


Fig. 21(a) (b) Excess penetration and lack of penetration

While two heavy duty batteries were in use, two reserve batteries were being recharged at the main base for the next day's operation. A light-weight ultrasonic set was used with 20° transverse wave probes, fitted with $2^1/_2$ mc/s quartz crystals as shown in Fig. 20. During the time that the ultrasonic investigation was in progress, strict records of each joint were kept and these were eventually compared with a separate set of records of gamma radiography of the same joints. Some difficulty was experienced in the interpretation as it was not possible to scan with the curved and fitted probes. Difficulty was also experienced in differentiating between lack of root penetration and excess penetration as is schematically shown in Fig. 21.

Shallower angle probes might have solved this problem but, as the pipes were factory bitumen coated, it would have necessitated considerable damage to the coating on each joint to get far enough back.

As the result of cross-check examination of over 3 miles of pipe line the conclusions were briefly that with further research and development in conjunction with the equipment manufacturers, it should be possible to ultrasonically examine the joints in a butt-welded pipe line with a greater degree of confidence than was established on the line in question.

Conclusions

While radioisotopes, from a purely academic and technical point of view, are not the most satsifactory method of nondestructive testing, it is considered that they do have many practical advantages, and that, with an adequate welding control system, correct exposure and development of radiographs and careful interpretation, they are capable of achieving the desired results.

After considering the many factors such as the radiation emitted, material, thickness, cost and short time for reactivation, it is felt that despite the 74-day half-life of iridium 192, this radioisotope is the most satisfactory source to use on the average transmission pipe-line weld radiography.

In the selection of films, the degree of fault detection must never be outweighed by the exposure speed and due consideration must be allowed for in the interpretation of "gamma graphs" for a lesser degree of sensitivity and a lower image contrast compared with X-radiographs.

Among the many other factors involved it is considered that the site conditions encountered are a major subject to be borne in mind when operating an over-all welding inspection and radiographic control service. The training and careful selection of site personnel can seriously affect not only the standard of welding, radiography and percentage of radiography but also the confidence of the engineer and welder in this method of welding supervision.

In the light of the nature of the pipe line and the justifiable expenditure, due consideration must be given to the advantages and disadvantages of various types of mobile laboratories, as these are seriously affected by the site conditions encountered.

While the total staffing for any method of welding inspection depends upon the size and nature of the project concerned, it is considered that the system of welding supervision discussed herein whereby both physical and radiographic control of welding are merged, is not only the most practical but also the most economic method of effecting welding control on transmission pipe lines.

The full benefits of both visual and radiographic inspection cannot be gained without the use and maintenance of some simple and accurate system of recording.

It is considered that if standard instructions on the handling and use of radioisotopes are issued to all the staff and steps taken to see that these are rigidly enforced, the industrial use of radioisotopes themselves presents no worse hazard than many other industrial substances.

Coupled with a cross-check percentage of gamma-radiography and with further research and development in conjunction with equipment manufacturers it should be possible in the future to ultrasonically examine the majority of welded joints in transmission lines at greater speeds than is possible today.

Acknowledgments

The author would like to thank the directors of Welding Supervision Ltd. and Costain-John Brown Ltd. for permission to publish this paper.

He also places on record his appreciation to his colleagues and associates who, too numerous to mention, assisted in the compilation of this paper.

Grateful acknowledgments are also made to the United Kingdom Atomic Energy Authority; Dr. J. S. Blair, E. N. Gilks, Gamma Rays Ltd. and others for permission to reproduce charts and other illustrations.

References

1. Laborde, M. A., "Les Services que peuvent rendre les rayons X dans les ateliers et dans les laboratories industriels," *Electricite et mechanique*, No. 19, 25–38 (July-August 1927).
2. Bates, C. C., "Gamma Radiography in Oil Storage Installations," *Petroleum*, August–October 1954.
3. Jefferson, S., private communication (June 1955).
4. Mullins, L., "The Scope of Gamma Radiography," *Journal Institution of Radio Engineers*, **15** (3), 131–141 (1955).
5. Blair, J. S., "Radio-Active Isotopes for Radiography," *Iron & Coal Trades Rev.*, 1–14 (Dec. 21–28, 1951).
6. Bates, C. C., "Ultrasonic Examination of 12 In. Diam Butt Welded Pipe Joints," unpublished report No. R26.
7. Eastwood, W. S., "Survey of Pile Made Isotopes for Industrial Radiography," Ministry of Supply/Atomic Energy Research Establishment, Unclassified document, AERE I/R385, 2nd issue, December 1949.
8. Recommendations of the British X-ray and Radium Protection Committee.
9. Recommendations of the International Commission on Radiological Units, I.C.R. Copenhagen, July 1953.
10. Brit. Pat. 22178/54.

LINDE UNVEILS INERT-GAS TUNGSTEN-ARC CUTTING OF ALUMINUM

Inert-gas tungsten-arc cutting of aluminum was successfully demonstrated by the Linde Air Products Co., a Division of Union Carbide and Carbon, at an editor's meeting held in their Newark Laboratories on Sept. 20, 1955. This new process, which shows great potential for becoming an extremely valuable tool in the shaping and fabrication of most nonferrous metals, produced sawlike quality cuts while the arc traveled at extremely high speeds.

Inert-gas tungsten-arc cutting employs an extremely high-temperature, high-velocity constricted arc between a tungsten electrode and the piece to be cut. The concentrated and columnated energy of the arc stream melts and ejects a thin section of metal to form a kerf. This jetlike action removes the molten metal mechanically, and the gas atmosphere prevents oxidation of the cut face.

Linde has devoted the majority of development of tungsten-arc cutting to aluminum applications. The company now plans to investigate thoroughly the possibilities of application of this new process to other hard-to-cut metals.

Best results are apparently obtained when employing a mixture of argon and hydrogen. For machine cutting the optimum mixture appears to be one containing 65% argon and 35% hydrogen. With this mixture a high arc voltage is developed. This arc voltage, however, can be obtained readily with a power supply having an open-circuit voltage of 100 v.

Fig. 1 Inert-gas tungsten-arc cutting of aluminum

In case of manual cutting it has been determined that the optimum mixture is approximately 80% argon and 20% hydrogen. The lower hydrogen content is employed in manual cutting in order to provide a greater tolerance for variation in arc length than required for machine cutting.

In manual cutting, pure argon is used for initiating and maintaining a pilot arc, prior to the starting of the cutting arc. With the initiation of the cutting arc, the required mixture is obtained by automatically adding hydrogen to the flowing argon.

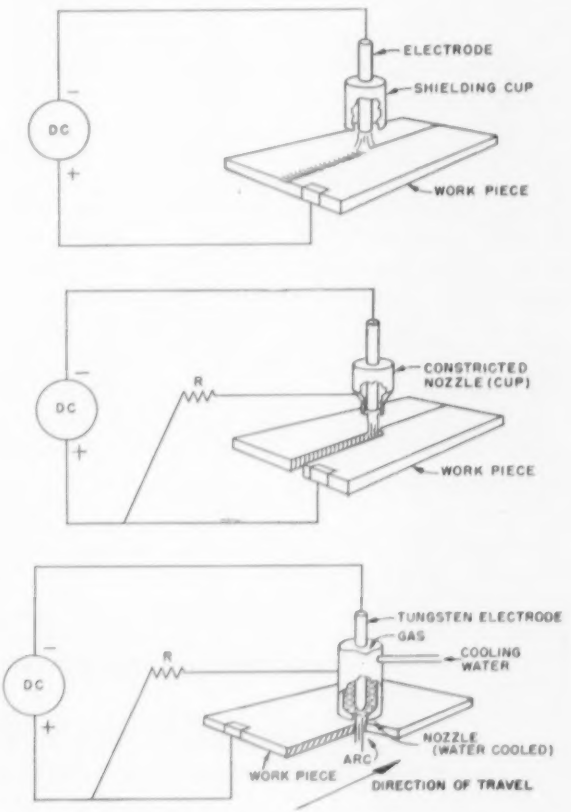


Fig. 2 Progressive schematic diagram of inert-gas tungsten-arc cutting

The top drawing is the normal tungsten-arc welding circuit. The second drawing shows the circuit changes, the addition of the pilot-arc circuit and gas-nozzle constriction, and the last drawing shows gas flow and the constricted arc characteristic of the inert-gas tungsten-arc cutting process

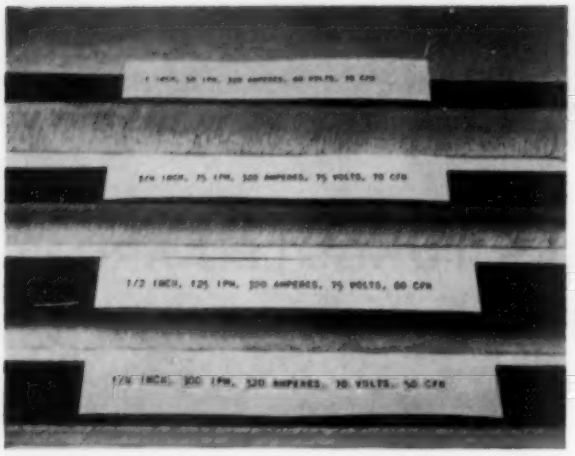


Fig. 3 These sawlike cuts were made in aluminum at high speeds

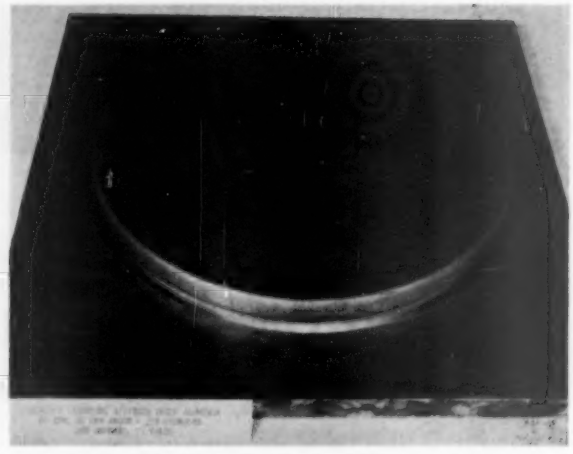


Fig. 4 Typical circular cut made on $^1/_2$-in. thick aluminum

In mechanized cutting, a standard high-frequency unit is used in conjunction with the pilot circuit to initiate the cutting arc.

When the point of cut is located and the main arc is initiated, the required flow of hydrogen is injected immediately. At the conclusion of the cut, the arc is automatically extinguished, and the argon and hydrogen stop flowing.

Since, as indicated previously, inert-gas tungsten-arc cutting is adaptable to mechanized or manual operations, it is expected to find immediate use in the aluminum fabricating industry. Until now, no simple means, with the exception of saws and planers, has been available for the cutting or edge-preparing of nonferrous metals. These processes have been generally limited to straight-line cuts, and the necessary equipment is generally expensive. In the cases where irregular or curved shapes must be cut, band-saws or hand-chipping and drilling methods have been used.

Now, inert-gas tungsten-arc cutting appears to have brought all the features of flame cutting to the cutting of aluminum. Normal mechanized cutting speeds of 300 ipm in $^3/_4$-in. plate and 50 ipm in 1-in. material are reported. If a lower-cutting speed, for example 20 ipm, is desired, it can be obtained simply by adjusting the controls. It can be used in any position for cutting straight lines, bevels, circles and shapes.

The speed and quality of manual cutting vary according to operator skill with an average speed of about 60 ipm on $^1/_2$-in. aluminum plate. The kerf edges of all cuts are relatively smooth, with square corners, and no attached dross.

This new process may well replace many cutting and edge-preparing methods presently used in the aluminum fabrication industry.

BOUND VOLUMES OF 1954 JOURNAL STILL AVAILABLE

Bound Volumes of THE WELDING JOURNAL for the year 1954 are available in black imitation leather covers, together with a comprehensive subject and authors index. Price $15, including postage.

This volume, comprising a total of 1238 pages in the JOURNAL and an additional 624 pages in the *Welding Research Supplement*, represents a veritable encyclopedia of information in the welding field. Copies may be ordered through the AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y.

TUNNEL LININGS PRODUCED ON PRODUCTION-LINE BASIS

A new and unusual construction product is being fabricated on a production line basis by Baldwin-Lima-Hamilton Corp., Philadelphia, Pa. This company is turning out 23 huge double-shell steel casings (total weight 50,600 tons) which will be used in building a vehicular tunnel under Hampton Roads, Va.

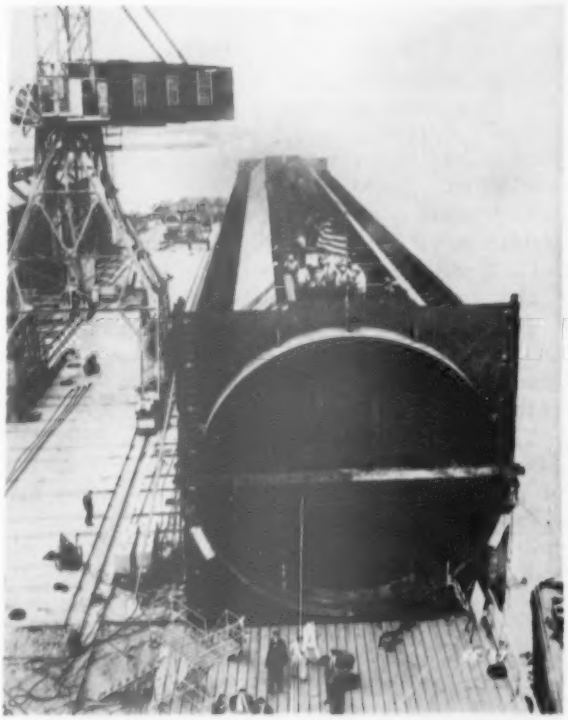
The subcontract for the tunnel lining calls for 6900 ft of double-wall casing in 23 sections, each of which is 300 ft long. The outer, octagonal-shaped wall of each section is 37 ft across flats, and the inner circular wall is 33 ft in diameter.

The massive sections are being fabricated by the Large Weldment Department, and then launched nearby into the Delaware River (see accompanying illustration). From here they are being towed on a 2-day trip via the Delaware River, Delaware-Chesapeake Canal, Chesapeake Bay and Elizabeth River to a "shape-up" station at Lamberts Point, Norfolk, about five miles from the tunnel site.

Before launching, the space between inner and outer walls is partly filled with concrete which acts as ballast. The open ends are then sealed with steel plate and the section is launched into the river. Upon arrival at the tunnel site, the final interior work, including the roadbed, will be completed before the sections are towed into position, sunk and locked into place in a dredged trench.

The finished tube will form the 6860-ft underwater part of a 4-mile span across "The Roads" from Willoughby Spit, near Norfolk, on the south shore to a point near Hampton on the north shore. The tunnel and its two approach bridges are the major features of a 23-mile Tidewater area improvement project described by the Virginia State Highway Department as the largest in its history. The crossing, a $19 million investment, is scheduled for completion late in 1957.

The fabricator constructed special press dies and welding fixtures to form the steel plate into shape and hold it in position for welding. Subsections of the tube, each 15 ft wide, are weld fabricated in the shop and then transported to the launching site on specially built cradles. The subsections, still remaining in their cradles, are then butted together to form a 300-ft launching tube, and welded into a continuous structure.



View of 300-ft welded steel tunnel section at time of launching

After welding is completed, the huge tube is moved over to the launching device. This consists of sloping steel ways down which a steel sled framework, driven by 20 electric motors, rides to carry the tube into the water.

Because of its immense size and weight, each tube must be moved inch-by-inch down the launchway and floated into the river at high tide. Once launched, it is made fast to a tug fore and aft and started on its journey to the tunnel site.

Based on a story by Baldwin-Lima-Hamilton Corp., Philadelphia, Pa.

WELDING CROSS-BEARERS FOR STEEL RAILROAD CARS

BY R. C. McMILLAN

By developing a special fixture, automatic submerged arc welding can put the fabrication of railroad car cross-bearers on a high production basis. The joints of these weldments are not straight, making it necessary to have a fixture to guide the welding heads along the contours of the joint.

A cross-bearer consists of five pieces of preshaped plate, one of which—the top cover—is approximately 10 ft long and bent in 10 places. Yet in a run of 2000 such units, an operator and a fitter, manning the fully automatic equipment, welded 40 assemblies per 8-hr day—or one every 12 min. The welding speed was 38 ipm.

Each assembly consisted of two $^3/_8$-in. bottom cover plates 8 in. x 3 ft 6, two $^1/_4$-in. webs almost 15 in. wide x 4 ft 4, and a $^5/_{16}$-in. top cover plate, 8 in. x 9 ft $4^1/_2$.

Four cross-bearers are required for each car.

The two webs were welded to the center of the top and bottom covers with an approximately 14-in. space between them to accommodate the center sill of the car.

The fixture consisted of a steel table made of two I-beams 10 $^1/_2$ ft long, 34 in. from the floor to the top of edgewise steel spacers for the webs. The five components to be welded were clamped in position with eight toggle clamps.

Two automatic heads and controls were mounted on a special self-propelled carriage which was made to ride on tracks paralleling the fixture (see Figs. 1 and 2). An outrigger rail extended out from this carriage over the work. The wire feed nozzles were attached to trolleys and fingers which ran crosswise on this outrigger rail. The fingers, which consisted of ball-bearing rollers mounted in rubber cushioners, straddled the edge of the top and bottom cover plates and guided nozzles along the web-cover-plate joints.

Both nozzles moved freely on the outrigger trolleys at right angles to the longitudinal feed of the automatic heads as the fingers felt their way along the seams. Both nozzles operated on the same outrigger rail, but each had its own set of rollers and was independently guided by its own set of fingers.

Because of the deep penetration of the submerged arc process, only one side of the joints was welded and the job was completed with a $^1/_4$-in. fillet in one pass. Thus, when the components were clamped in the fixture and checked for alignment, the automatic heads were simply sent once across the work and the assembly was ready to be taken out to the next station.

The fillet was made consistently at the rate of 38 ipm using 29 to 30 v, 550 amp, $^1/_8$-in. wire and 760 flux.

Based on a story prepared for the Lincoln Electric Co.

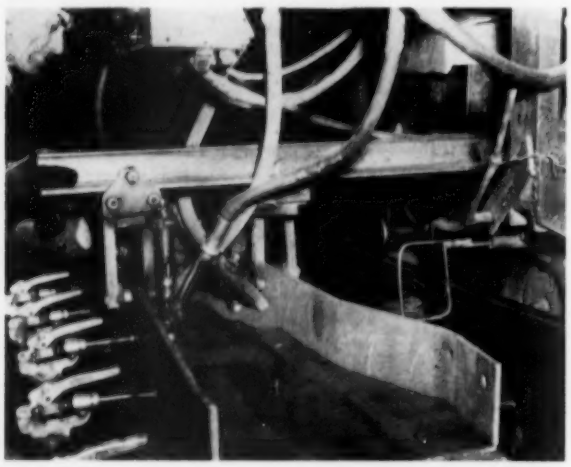


Fig. 1 Using submerged arc equipment to weld a railroad car cross-bearer

The two wire feed nozzles were attached to trolleys which ran crosswise on the outrigger rail. Rubber-cushioned ball-bearing fingers guided the nozzles along the joints as the whole assembly moved across the work, which was almost 10 ft long. The two fingers moved independently of each other.

Fig. 2 Using this specially designed fixture and two fully-automatic submerged arc welders, the fabrication of railroad car cross-bearers can be put on a high production basis

The two automatic heads rode on tracks seen at the left, their nozzles being guided by fingers on the outrigger rail.

Fig. 1 This welding operator is braze welding a tubular joint of a seat subassembly; the welded subassemblies are placed in a master jig and braze welded into a single unit

Fig. 2 This steel frame for an electrically driven wheel chair has more than 60 braze-welded joints; its welded tubular construction makes the frame strong yet light

MOTORIZED CHAIR GIVES INVALIDS A LIFT

Braze-welded electric wheel chair is just what the doctor ordered

BY R. L. FULLER

An electrically driven wheel chair, with a braze-welded tubular steel chassis, is the latest mechanical aid designed for the locomotion of the elderly and the handicapped. Thirty pieces of $^1/_2$-in. tubing are oxy-acetylene braze welded into each unit, giving the chair strength and durability without excess weight.

More than 60 braze welds are required to join the many sections of tubing. The braze-welded joints are strong and highly resistant to corrosion, thereby contributing to the long life of the car. The process is fast and economical.

The tubular chassis is braze welded in five separate subassemblies, in specially designed jigs. A welding operator clamps the tubing in place and cleans the weld areas thoroughly with a wire brush. Flux is then applied to the weld areas, after which the operator preheats them to a dark red color. He then proceeds to weld, using $^1/_{16}$- to $^1/_4$-in. bronze rod. Welds are sound and free from impurities. The welded subassemblies are placed into a master jig and braze welded into a single unit. A light grinding of the weld areas removes excess metal. Following this, the chassis is painted and made ready for installation.

R. L. Fuller is associated with Linde Air Products Co., New Orleans, La.

Fig. 3 A flexible, nondenting, plastic body gives the electric car a trim appearance; the car's oxy-acetylene braze-welded construction assures many years of service

ALUMINUM WINDOW FRAMES FABRICATED BY INERT-GAS TUNGSTEN-ARC WELDING

BY W. J. HANCE

A manufacturer in the southwest has recently combined inert-gas tungsten-arc welding and special jigs to set up a highly efficient production line for the fabrication of aluminum window frames. Inert-gas tungsten-arc welding provides sound, corrosion-resistant welds of the all-aluminum sections.

Two different styles of jigs are used. One type accommodates the $^1/_4$-in. thick sections of casement window frames, and the other is used to align and hold the $^3/_{32}$-in. thick pieces of double-hung frames(see Figs. 1 to 3). The jig clamps can be released or secured with a single action, allowing quick, easy handling of both the jig and the finished frame. The parts are jigged and the four corner welds made in less than ten minutes.

The operator uses an inert-arc welding torch with a $^1/_8$-in. diameter standard tungsten electrode to make the inert-gas tungsten-arc welds in the type 63S aluminum used for these window frames. The joints are first prepared with a single vee, and then cleaned of grease and oxide.

The method of welding is the normal technique for inert-gas tungsten-arc welding of aluminum, using a $^1/_8$-in. aluminum filler rod to add metal to the weld joint.

W. J. Hance is associated with the Linde Air Products Co., San Francisco, Calif.

Fig. 1 The operator is about to start a corner weld in a $^1/_2$-in.-thick aluminum window frame; finish grinding is kept to a minimum because inert-gas tungsten-arc welding is used

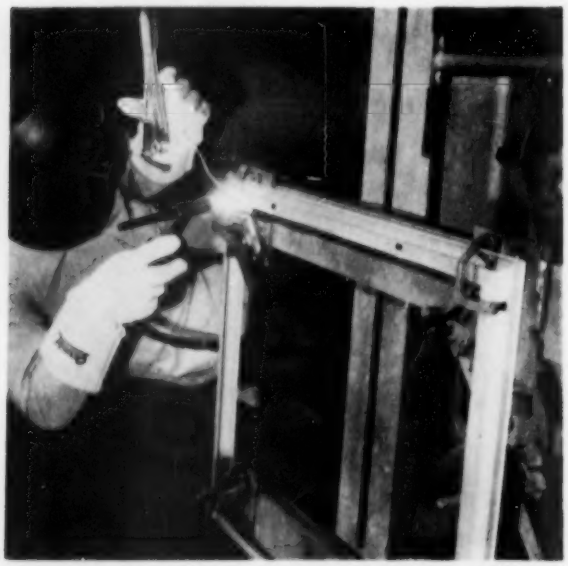


Fig. 2 The parts of each frame are lined up quickly and set securely in this clamp jig; when the welds are completed, each clamp is released by a single action

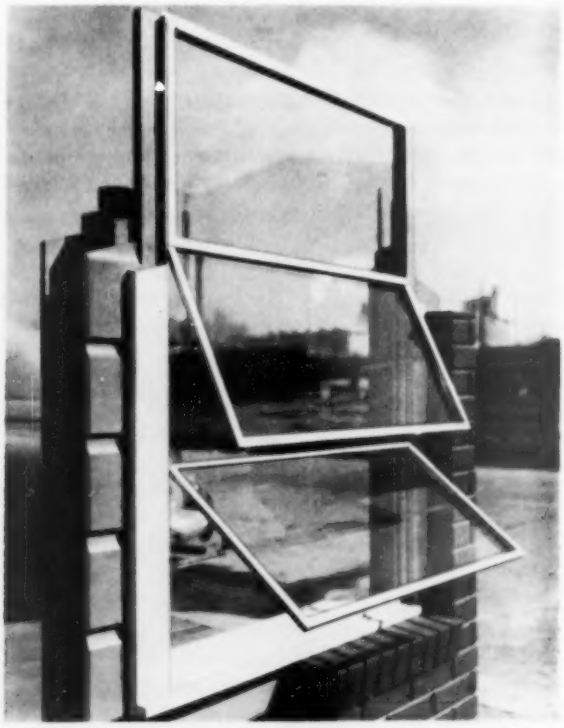


Fig. 3 The finished window frame is corrosion resistant, and is ready for all kinds of weather; the inert-arc welds are almost invisible

DISTORTION CUT IN WELDING OF GIANT I-BEAMS

Skillful job positioning and the use of a submerged-arc welding machine made possible recently the fabrication of 60-ft I-beams with flange warpage as low as $^1/_{32}$-in. at Orleans Material and Equipment Co., Inc., New Orleans, La. It is estimated that the beams, which are to be used as bridge girders by a Southeastern highway system, were submerged arc-welded at half the cost of a similar operation using manual metallic arc welding.

Each I-beam measured 40 in. x 60 ft, with $^7/_8$ x 14-in. flanges and a $^3/_8$-in thick web. Web and flanges were ASTM-A7 steel. A $^5/_{16}$-in. fillet weld was made in each of the four joints formed by the beam sections.

First, all scale and foreign matter were wire-buffed or ground from the areas to be welded. Then, a series of gusset plates and C-clamps, spaced at 5-ft intervals, were used to lock the flanges to the web to insure a square joint. Since job specifications did not permit tack-welding of the flange to the web, the C-clamps were tacked the to gusset plates which, in turn, were tack-welded to the web plate, as shown in Fig. 1. Pressure screws on the C-clamps tightened the assembly.

Based on a story supplied by the Linde Air Products Co.

The unit was positioned in a welding fixture and set at a 30° angle, with the jigged side down. This left the other side clear for welding. Strongbacks, flame-cut from $^3/_4$-in. plate, were then placed over the flange to be welded. Steel wedges were driven into the space between the strongbacks and the face of the flange, applying pressure on its outer edges and restraining drawing due to contraction during welding. Figure 2 shows the strongback arrangement.

Submerged-arc welding apparatus, mounted on a machine carriage, welded the flange to the web at a speed of 18 ipm. A guide wheel led the welding machine along the joint and eliminated positioning adjustments during the operation. On completion of the first weld, the beam was repositioned and the top flange was welded. The beam was turned over, the gusset plates and C-clamps removed and the strongbacks replaced. This side was then welded by the same method as described above.

The completed welds required no finishing. Distortion had been held to much closer tolerances than would have been possible had metallic arc welding been used.

Fig. 1 A series of gusset plates and C-clamps are used to square-up the flanges to the web plate of this 60-ft I-beam prior to welding. The C-clamps are tack-welded to the gusset plates, which are tack-welded to the web plate, leaving the underside clear for submerged arc welding

Fig. 2 A submerged-arc welding machine welds a flange to the web at 18 ipm. Steel wedges are driven between strongbacks and the face of the flange to prevent drawing during the welding operation. Distortion was held down to as low as $^1/_{32}$ in. by this method

Society News

Educational Program in Welding Technology Fostered by Philadelphia Section

The Sept. 19, 1955, meeting of the *Philadelphia* Section marked the institution of another phase of AWS Section participation in education—the sponsoring of a welding laboratory at the Drexel Institute of Technology in Philadelphia and the lending of all-out assistance by that AWS Section toward the institution of an adequate educational program in Welding Technology. The meeting was held at the Drexel College Auditorium.

Prior to the technical session, Drexel tendered a dinner to honor donors of welding equipment and members of the Sections educational committee for their efforts in providing a welding laboratory for the Institute. Dr. James Creese, President of Drexel, spoke briefly on Industry-Education relationship in the field of technology. S. Baum, Chairman of the Educational Committee, acknowledged all donors of equipment and expressed the gratitude of both Drexel and AWS for their assistance in promoting education in the field of welding technology. Mr. Baum stated that the great need for technically trained welding personnel in the Delaware Valley area prompted the Section to assist the fabricating industry by sponsoring courses in welding engineering at the Drexel Evening College.

It is the desire of the Section to have eventually the present courses incorporated in an engineering curriculum leading to a diploma or degree in Welding Engineering at Drexel. The new Laboratory will greatly enhance this program as well as provide facilities for future work in welding research on a graduate level. However, such a program cannot be realized unless the fabricating industry itself expresses its desire to have engineering personnel trained in welding technology.

National President Joseph H. Humstone, National Secretary Joseph G. Magrath, and Technical Secretary Simon Greenberg, were among the invited guests at the dinner. Also attending were local leaders of industry, Section officers and Engineering Department heads of the Institute. In all, 100 were in attendance, at the dinner. Immediately following the dinner, a tour of the Welding and Metallurgical Laboratories was conducted by members of the Drexel Staff. A pictorial exhibit of welding as applied in local industry was a feature of the tour. The displays were prepared by 25 companies for this meeting and were to remain at the Institute to facilitate the teaching of welding engineering.

The technical meeting was addressed by Mr. Greenberg, whose subject was "The Design of a Welding Procedure." Mr. Greenberg covered the basic parts of a welding procedure, directing his remarks to those people primarily responsible for the design and fabrication of welded structures. He stated that each joint design requires a specific procedure which in most cases can be made applicable to more than one project. The marking of a joint on a drawing with an arrow and a notation "sound weld" is today inadequate and superficial.

The speaker stressed that in order to realize the economical advantages of welding as a means to fabrication, a welding procedure must be designed around the connection with consideration to service, materials, process and costs.

The presentation was well received by the 225 in attendance as indicated by the length of the discussion period.

INSPECTING WELDING EXHIBIT AT DREXEL INSTITUTE

Model of proposed all-welded prefabricated tunnel section for Patapso River holds the close attention of Prof. H. M. Pfeffer of Drexel, National Secretary Joe Magrath, Technical Secretary Si Greenberg, Philadelphia Educational Committee Chairman Sam Baum, and AWS President Joseph H. Humberstone. Picture was taken during meeting of Philadelphia Section on Sept. 19th

TAC TALKS

FILLER METAL—II

Filler Metal for Welding Cast Iron

by H. V. Inskeep

Early in 1954 a subcommittee was formed to write specifications for filler metals for welding cast iron. As finally organized the subcommittee has 13 members including the chairman. The members represent filler metal manufacturers, users of cast-iron filler metals and manufacturers of welding equipment. With this cross section of the industry it has been possible to approach the problem of specifications for cast-iron filler metals logically and with a sound background.

Meetings have been held and good progress has been made. Tentative analyses, performance standards and methods of testing have been generally agreed on. An appendix has been completed.

Cast-iron filler metals have and are being used for repair, salvage and maintenance work. The need for specifications for ordering these materials has never been thought of great importance until recently. The materials on the market for the welding of cast iron have been satisfactory generally. However, with the increase of more precise management control and the desire to specify the quality and performance of all items purchased, a need for the specification of cast-iron filler metals has made itself apparent.

The committee has for its purpose to provide these specifications, including a method of testing or checking the usability of electrodes purchased. Cast-iron filler metals will then be included in the long list of materials which are presently being purchased and sold under a pertinent specification. This situation will be of great help to both the purchaser and user of these materials as the specifications will make it more difficult for materials of poor quality to reach the market.

H. V. Inskeep is Chairman, Subcommittee X, AWS-ASTM Committee on Filler Metal, and Process Supervisor, Linde Air Products Co.

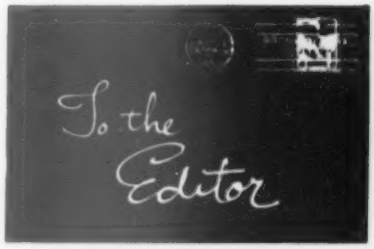
Nickel and Nickel Alloy Filler Metal

by O. B. J. Fraser

Committee work in 1954 has resulted in the publishing of Tentative Specifications for Nickel and Nickel-Base Alloy Covered Welding Electrodes (ASTM B-295-54T; AWS A5.11-54T). These specifications include electrode classifications for Monel, nickel, Inconel, "K" Monel, Inconel "X," Hastelloy Alloy "B" and Hastelloy Alloy "C" electrodes for shielded metal-arc welding. These electrodes have never been covered by specifications before.

Committee work now in process includes the preparation of Specifications for Nickel and Nickel-Base Alloy Bare Welding Filler Metals for oxy-acetylene welding, atomic hydrogen arc welding, inert-gas metal-arc welding with consumable electrodes, and inert-gas metal-arc welding with nonconsumable electrodes. The alloys for which classification will be provided include Monel, nickel, Inconel, Silicon-Monel, "K" Monel, Inconel "X," Nimonic "75," Hastelloy Alloy "B," Hastelloy Alloy "C" and Hastelloy Alloy "W." It is hoped that these specifications can be issued in 1955.

O. B. J. Fraser is Chairman, Subcommittee V AWS-ASTM Committee on Filler Metal, and Assistant Manager, Development and Research Division, International Nickel Co.



WELDED BRIDGES

Dear Sir:

In a current issue of a business weekly magazine, it is reported that constant flexing by traffic of the structure of the San Francisco Golden Gate Bridge has caused its rivets to work loose. One by one these rivets are being replaced with bolts.

Other bridges and riveted structures have had the same difficulty with loose rivets.

If these bridges had been built with welded construction, which is the simplest yet strongest way to fabricate steel structures, this extremely expensive procedure of replacing rivets would never be necessary. Furthermore, leading structural authorities state that welded bridges can be and are built with

AT THE FRONTIERS OF PROGRESS YOU'LL FIND

AN AIR REDUCTION PRODUCT

FOR WELDING AND CUTTING...

IN THE RED DRUM

HIGHEST QUALITY

DUST-FREE

NATIONAL CARBIDE

Write for the name and address of the NATIONAL CARBIDE supplier nearest you.

National Carbide Company

GENERAL OFFICES: 60 EAST 42ND STREET, NEW YORK 17, N. Y.

A DIVISION OF AIR REDUCTION COMPANY, INCORPORATED

METALLURGISTS

PROCESS
LABORATORY
WELDING

Challenging opportunities open in aircraft process metallurgy for graduates

•

JUNIOR METALLURGISTS

•

METALLURGISTS

•

WELDING AND PROCESS ENGINEERS

•

Outstanding men without degrees —but with equivalent experience—will be considered.

Send resume, recent photograph and salary requirements to

B. R. Toudouze

CONVAIR

A Division of General Dynamics Corporation

Fort Worth, Texas

at least 20% savings in the amount of steel used.

European countries have had a long successful experience of saving steel with not only welded bridges of long spans, but also all types of steel structures. For almost 20 years, highway and railroad bridges built in Sweden have been welded.

Why, with the evidence before us proving the advantages of welded construction, we in the United States are slow to take this step of progress is difficult to understand. Some states have adopted policies of using welded construction and others are presently considering it. Nevertheless our educators, schools, highway officials and the people who design and make bridges and other steel structures have a responsibility to make this progress as rapidly as possible.

The country is undertaking a gigantic road building program which will entail the building of many bridges with public funds. Will these bridges be obsolete before they are built?

Very truly yours,

C. G. Herbruck

Assistant to the Secretary
The Lincoln Electric Co.
Cleveland, Ohio

EMPLOYMENT SERVICE BULLETIN

Positions Vacant

Consultant Metallurgist—$8990 per annum—candidates should have broad experience in welding metallurgy and laboratory test procedures.

Welding Engineer—$6390 per annum—with metallurgical background in the development of welding procedures.

Welding Engineer—$4930 per annum—with degree in metallurgy and some knowledge of welding procedures.

Applicants for the above positions should write to the Industrial Relations Officer, U. S. Naval Engineering Experiment Station, Annapolis, Md.

V-327. Welding engineers at high technical and supervisory levels in quality control and inspection supervision of welding and metals fabrication. An unequaled opportunity with leading well-established firm in a new and expanding industry. Location Pittsburgh, Pa. A degree in metallurgy and 3–15 years' experience in code welding of stainless or other control of metallurgical operations, metals fabrication or field inspection are required. Submit a complete resume and state salary requirements.

WESTINGHOUSE ATOMIC POWER

has openings for:

METALLURGISTS

and

WELDING ENGINEERS

At high technical and supervisory levels

In quality control and inspection supervision of welding and metals fabrication.

A degree in metallurgy and 3-15 year's experience on code welding of stainless or other control of metallurgical operations, metals fabrication or field inspection are required.

SALARY OPEN

Please send detailed resume, including past earnings to:

A. M. Johnston
Westinghouse Electric Corp.
PO Box 1468
Pittsburgh 30, Pennsylvania

All replies held strictly confidential

Services Available

A-680. Welding Supervisor. 25 years' experience in welding and related activities seeks position outside U. S. A. Ten years with major construction and oil companies on foreign work. Ample experience in structural, tank, pressure and process piping and vessels; training and certifying welders; testing; inspection, metallography, weld treatment; ferrous, nonferrous, austenitic metals. Most processes. Available immediately.

WELDING ENGINEER

Expanding programs in welding, brazing and soldering have created an opening for a welding research engineer. This is an opportunity for diversified experience in joining. Salary commensurate with experience and training. Liberal employee benefits include generous tuition refunds for graduate study. Write:

Mr. T. E. DePinto
ARMOUR RESEARCH FOUNDATION
of Illinois Institute of Technology
10 West 35th St.
Chicago 16, Illinois

WELDING ENGINEER

Must have Engineering Degree, minimum two years Welding Engineer experience, with knowledge of aircraft quality requirements desirable; position is at Supervisory level with attractive salary, advancement opportunities, a profit sharing program, advanced vacation plan, group insurance and other benefits. Company is a leader in the field of high alloy steel products for jet engines and commercial use.

SOLAR AIRCRAFT COMPANY
Des Moines, Iowa

Section News and Events

as reported to Catherine O'Leary

New Section Officers for 1955–56 Fiscal Year

The names of some of the new AWS Section Officers for the 1955–56 fiscal year have been given in previous issues of THE WELDING JOURNAL. Listed below are the additional officers whose names have been received at AWS headquarters during the last month. If needed, the individual addresses may be obtained by writing to the Section Secretaries.

Cincinnati—Chairman, John Reininger; 1st Vice-Chairman, C. T. Whelan; 2nd Vice-Chairman, N. Woods; Chairman Membership Committee, N. Woods; Chairman Program Committee, Joe Hall; Technical Representative, H. E. Schultz; Secretary-Treasurer, Kenneth R. Rouff, 11756 Kenn Rd., Springdale, Glendale P. O. Ohio.

Dallas—Chairman, G. Q. Mays; Secretary, A. A. Stiles, Rt. 2, Box 95, Arlington, Tex.

Detroit—Chairman, J. E. Rainey; 1st Vice-Chairman, Wm. H. Smith; 2nd Vice-Chairman, H. V. Beronius, Jr.; Chairman Membership Committee, Jack Lemon; Chairman Program Committee, Arthur W. Brown; Technical Representative, Prof. L. E. Wagner; Secretary-Treasurer, J. R. Stitt, Box 4666, c/o the R. C. Mahon Co., Detroit 34, Mich.

East Texas—Chairman, I. M. Thompson; 1st Vice-Chairman, T. D. Delk; 2nd Vice-Chairman, E. C. Frye; Treasurer, R. C. Woods; Chairman Membership Committee, E. C. Frye; Chairman Program Committee, T. D. Delk; Technical Representative, Fred Salmons; Secretary, J. B. DuBose, 109 Peterson Ct., Longview, Tex.

Hartford—Chairman, T. A. Risch; Co-Vice-Chairman, J. St. Cyr; 2nd Vice-Chairman, M. Kenyon; Treasurer, V. Dzon; Chairman Membership Committee, F. Johnson; Chairman Program Committee, G. Kirkley; Technical Representative, J. Mortimer; Co-Technical Chairman, H. McGlew; Secretary, W. A. Duncklee, Chas. Pfizer & Co., Inc., Groton, Conn.

Portland—Chairman, Walter L. Wyman; 1st Vice-Chairman, Earl Babbitt; Treasurer, Paul Buck; Secretary, Lawrence Kissler, Linde Air Products Co., 1205 N. W. Marshall St., Portland, Ore.

Richmond, Va.—Chairman, M. J. Hipwell; 1st Vice-Chairman, Frank Chandler; 2nd Vice-Chairman, J. T. Michie; Treasurer, C. G. Dillard; Chairman Program Committee, Frank Chandler; Secretary, F. D. Duffey, 1711 Oakhill Lane, Richmond, Va.

Sangamon Valley—Chairman, Jerome P. Hertel; 1st Vice-Chairman, G. A. Rehm; Treasurer, Earl Floreth; Chairman Membership Committee, L. L. Baugh; Chairman Program Committee, C. W. Dawson; Technical Representatives, J. D. Brown and Park Boyer; Secretary, F. E. Moore, 2059 E. North, Decatur, Ill.

Tulsa, Okla.—Chairman, L. F. Douglas; 1st Vice-Chairman, Henry Ping; 2nd Vice-Chairman, Bill Jaggers; Treasurer, Fred Dorrell; Chairman Membership Committee, Roland Nichols; Chairman Program Committee, Henry Ping; Technical Representative, Art Ryan; Secretary, Ben Walcott, Box 870, Tulsa, Okla.

SECTION MEETING CALENDAR

NOVEMBER 29th

Northwestern Pennsylvania Section. Erie, Pa. "European Welding Methods," by R. W. Clark, Supervisor, Welding Laboratory, Schenectady Works, General Electric Co.

DECEMBER 2nd

North Central Ohio Section. Marion. Dinner, Movie, speaker, question and answer period.

DECEMBER 5th

Lehigh Valley Section. Bethlehem, Pa., "Plant Management," by J. J. Kennedy, R. C. Mahon Co., Detroit, Mich.

DECEMBER 9th

Detroit Section. Annual Stag Party.

DECEMBER 12th

Northwest Section. Minneapolis, Minn. "Research Metal Stresses Weldments," by T. P. Hughes, University of Minnesota, will present slides and movies.

DECEMBER 13th

Dayton Section. 8 p.m. Dayton Engineers' Club. "CO_2 Welding and Cutting" by Edward Vogel, Research Engineer, The Liquid Carbonic Corporation.

New Jersey Section. National Officers Night. Hotel Essex House, Newark, N. J. "Evaluating the Iron Powder Coated Electrodes for Production Use," by Donald B. Howard, American Car & Foundry Div., A. C. F. Industries.

DECEMBER 14th

Cleveland Section. Hotel Manger. Dinner 6.30 p.m. "Low Temperature Joining of Non-Ferrous Metals," by A. W. Swift, Welding Engineer, Handy-Harman.

DECEMBER 15th

Madison, Wis., Section. Eagles Club. "Advances in Resistance Spot Welding," by Karl W. Matthes.

DECEMBER 16th

Northwest Section. Minneapolis, Minn. Christmas Party. Francis Drake Hotel.

Richmond Section. Christmas Dinner and Dance at Forest View Supper Club, 4804 Midlothian Pike, Richmond, Va.

Editor's Note: Notices to be published in any one given issue must reach Journal office not later than the first of the preceding month. Give full information concerning time, place, topic and speaker for meeting.

IRON-POWDER ELECTRODES

Albuquerque, N. Mex.—Harry F. Reid, manager, Technical Service Division, McKay Co., was the technical speaker at the September dinner meeting of the *Albuquerque* Section held at Leonard's Restaurant. Mr. Reid's subject was "Iron Powder Electrodes—Yes or No?"

Installation of incoming officers took place before the technical meeting.

QUALIFICATION OF WELDERS

Chicago, Ill.—The principal speaker at the regular monthly dinner meeting of the *Chicago* Section held on Friday evening, September 16th, at the Peoples Gas, Light & Coke Co., was Frank M. Swengel, manager of the Power Piping Department of the William A. Pope Co., Chicago. Mr. Swengel's talk was concerned principally with qualification of welders who work on or with piping.

Speaker Frank M. Swengel

Immediately following dinner, and just before the meeting got under way, three short educational films, starring golfer Tommy Armour, were shown with a view to helping members brush up on their game before the golf outing.

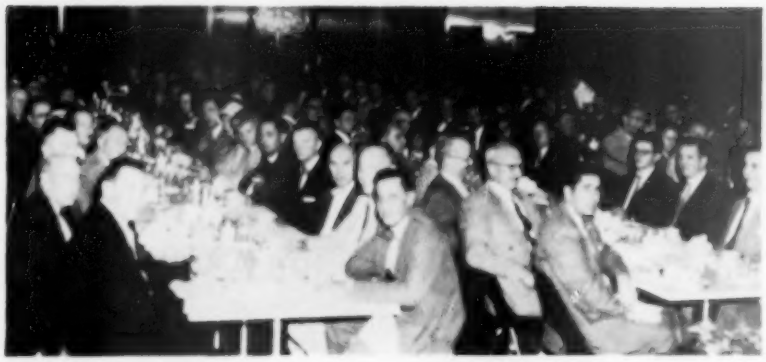
FLAME PLATING

Denver, Colo.—The *Colorado* Section held its September dinner meeting on September 13th in the Festival Room of the Oxford Hotel.

Coffee speaker was Eugene Hultman of the Colorado National Bank. His subject, "Checks After You Write Them," was very interesting.

The main speaker was M. L. Powers of the Linde Oxygen Co. Mr. Powers told how they use flame plating with tungsten carbide, a surfacing material for parts subjected to a great deal of wear. This material is applied at a very low heat. Slides and samples were also shown.

DETROIT SECTION VISITS GM PLANT



Part of large dinner group

(Left) Standing, P. Beck, GM, J. R. Stitt, AWS, W. H. Smith, AWS, C. Morse, GM. *(Seated)* W. Wakeman, GM, M. Carpenter, GM, J. E. Rainey, AWS, L. T. Kendall, AWS. *(Right)* Detroit Section Chairman J. E. Rainey (on left) thanking M. Carpenter, GM Technical Center public relations for splendid evening

PLANT VISIT

Detroit, Mich.—The *Detroit* Section's activities for the 1955–56 season were started with the traditional plant visitation. The number and enthusiasm of those attending the opener gave promise of a most successful year to follow.

The new General Motors Technical Center, located on 813 acres a few miles north of Detroit, proved to be far too big for a single evening's coverage but the parts which were visited left no doubt that a new wonder has been added to the neighborhood. Nearly 200 members and guests gathered for dinner in the main cafeteria, which would do justice to a lavish club. Films were shown giving a colorful view of car designing. Small groups were then taken through the administration sections, the power plant and some of the laboratories. The entire center includes 17 major buildings and several utility buildings and is to be occupied by General Motors Engineering Staff, Research Laboratories, Process Development, and Styling. It was satisfying to observe that all of the structural steel connections are welded.

INERT-ARC WELDING

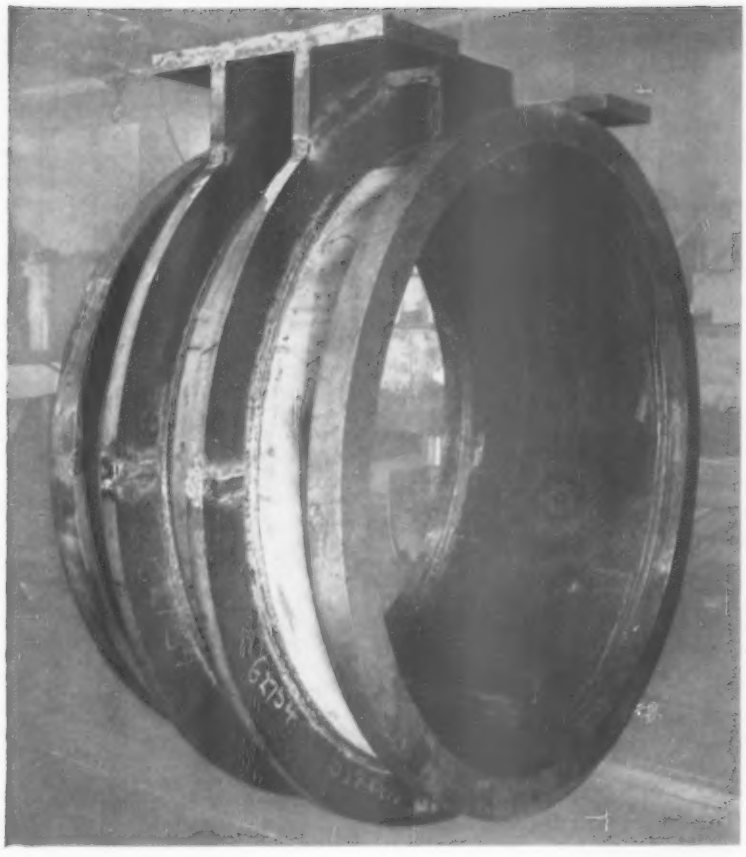
Hartford, Conn.—The *Hartford* Section opened its 1955–56 season with a dinner meeting on September 15th at the Villa Maria Hotel in Glastonbury.

After an excellent steak dinner enjoyed by the 40 attending members and guests, Chairman Risch introduced J. Warden Cunningham of the Air Reduction Corp. Formerly a research engineer with Airco, he now holds the position of product sales manager for inert-gas-welding equipment.

Mr. Cunningham gave a very comprehensive talk on "New Developments in Inert-Gas-Shielded Arc Welding." He covered fully the field of Argon, Helium, and CO_2 shielding gases, and with the aid of slides and a movie brought this subject up to date on this very important phase of the welding industry.

HARTFORD PROGRAM

Hartford, Conn.—A schedule of



HENRY

PRATT

COMPANY

welds 3½% Nickel Steel in half the time with

ATOM•ARC

8016N
IRON POWDER LOW HYDROGEN ELECTRODES

For nearly thirty years, the Henry Pratt Company of Chicago has specialized in the designing and building of many types of butterfly valves. The fabricated body shell illustrated above is an example of an unusual butterfly valve made for an unusual service. Installed in a closed-circuit controlled-atmosphere wind tunnel, this Stressed Seal* Butterfly Valve must withstand transonic velocity air streams at temperatures ranging from —100°F. to +650°F.

*Copyright Henry Pratt Co.

REDUCING cost approximately 50% was the remarkable result of the Henry Pratt Company, Chicago, Illinois, changing to ATOM • ARC 8016N iron powder, low hydrogen electrodes.

The Henry Pratt job was the fabrication of 66″ and 48″ Butterfly Valve bodies of 3½% nickel steel to be used in a closed-circuit, controlled-atmosphere wind tunnel. By using ATOM • ARC 8016N electrodes, the company eliminated costly and troublesome pre-heat procedures making available more man-hours for production welding. Easier *all-position* welding and cutting down on slag cleaning time brought greater weldor ease and comfort. The weld deposit rate was increased 30% with no appreciable spatter loss and there was no porosity or cracking of any kind in the welds.

The cost-saving experience of the Henry Pratt Company has been duplicated in plant after plant. That is why it will pay you to use ATOM • ARC . . . the *all-position*, iron powder, low hydrogen electrode.

Alloy Rods Co.

Get your free copy of this DATA SHEET on ATOM • ARC 8016N. It includes complete information on Application, Description, Identification, Physical Properties, Chemical Analyses and Welding Procedure. For your free copy write:

ALLOY RODS COMPANY

General Offices and Plant
Lincoln Highway West
YORK 3, PENNSYLVANIA

Pacific Coast Sales Offices and Plant
750 Lairport Street
EL SEGUNDO, CALIFORNIA

speakers and meeting places for the remainder of the season of the *Hartford* Section is as follows:

January 17th—International Nickel Co. speaker at Villa Maria, Glastonbury.

February 16th—"Design and Construction of Field Erected Storage Vessel," Fred L. Plummer of the Hammond Iron Works, Warren, Pa., Meeting at the Griswold Inn, Essex.

March 20th—"Oxygen and Acetylene, Handling, Cutting and Associated Process," J. S. Douglas, Linde Air Products. Meeting at Villa Maria, Glastonbury.

April 17th—Annual plant visitation, Wallingford Steel Co., Wallingford. Dinner at Oakdale Tavern on Yankee Silversmith.

May 18th—Election of officers at Lighthouse Inn, New London.

PROGRAM OF MEETINGS

Moline, Ill. The *Iowa-Illinois* Section announces the following calendar meetings for the remainder of the season. All meetings will be held at 7:30 p.m. in the American Legion Club, Moline.

Jan. 12, 1956—"Fundamentals of Resistance Welding," A. Leslie Pfeil, Universal Welder Corp.

Feb. 9, 1956—"Consumable Electrode Welding with CO_2 Gas Shielding," Bob Mann, General Electric Co.

Mar. 8, 1956—"New Developments in Submerged Arc Welding," R. A. Wilson, Lincoln Electric Co.

Apr. 12, 1956—"Resistance Welding Controls and Their Functions," J. W. Brown, Square D Co.

May 10, 1956—"Arc Welding Machines, AC and DC," Unnamed, Hobart Brothers.

SOCIAL MEETING

Kansas City, Mo.—The fall and winter sessions of the monthly meetings of the *Kansas City* Section opened with a "bang-up" social meeting held at the Cypress Room of the Muehlebach Brewing Co. Besides enjoying the delicious brew furnished by Muehlebach, the members enjoyed also a marvelous barbeque dinner prepared by the California Caterers. There was an excellent turn-out for this affair held on September 8th and the Section feels that the sociability and friendship gained at this meeting will strengthen the Section so that it will have an increasingly better attendance at their monthly technical meetings.

The Section wishes to take this opportunity to express its appreciation to all AWS members who attended the National Spring Meeting in Kansas City. They hope that all who participated had a profitable and enjoyable time in their city, and that fond memories of that occasion will speed their return to Kansas City, the Heart of America.

SCHEDULE OF MEETINGS

Bethlehem, Pa.—The *Lehigh Valley* Section announces the schedule of meeting dates, speakers and topics for the remainder of the season:

Jan. 6, 1956—"Battle of the Cities," Chairman—L. J. McGeady.

Feb. 6, 1956—"Evaluating Iron Powder Electrodes," by Jerry Hinkel, Lincoln Electric Co.

Mar. 5, 1956—Joint meeting with ASCE "Structural Welding Design," by T. C. Kavanaugh, Consulting Engineer, Praeger & Kavanaugh, New York, N. Y.

Apr. 2, 1956—"Demonstration Night," Chairman—L. R. Constantine.

May 4, 1956—Annual Meeting & Ladies Night, Chairman—J. L. Walmsley.

MAINTENANCE

Hollis, L. I.—The first dinner meeting of the new season of the *Long Island* Section was held at Patricia Murphy's Candlelight Restaurant, Manhasset, L. I., on Thursday evening, September 8th. All future meetings of this Section for the season will be held at this location on the second Thursday of each month.

The guest speaker was Nelson Inman AWS of Republic Aviation Corp., Farmingdale, L. I. Mr. Inman's instructive talk dealt primarily with the maintenance and servicing of electronic tubes used in resistance welding equipment.

SIMPLIFIED METALLURGY

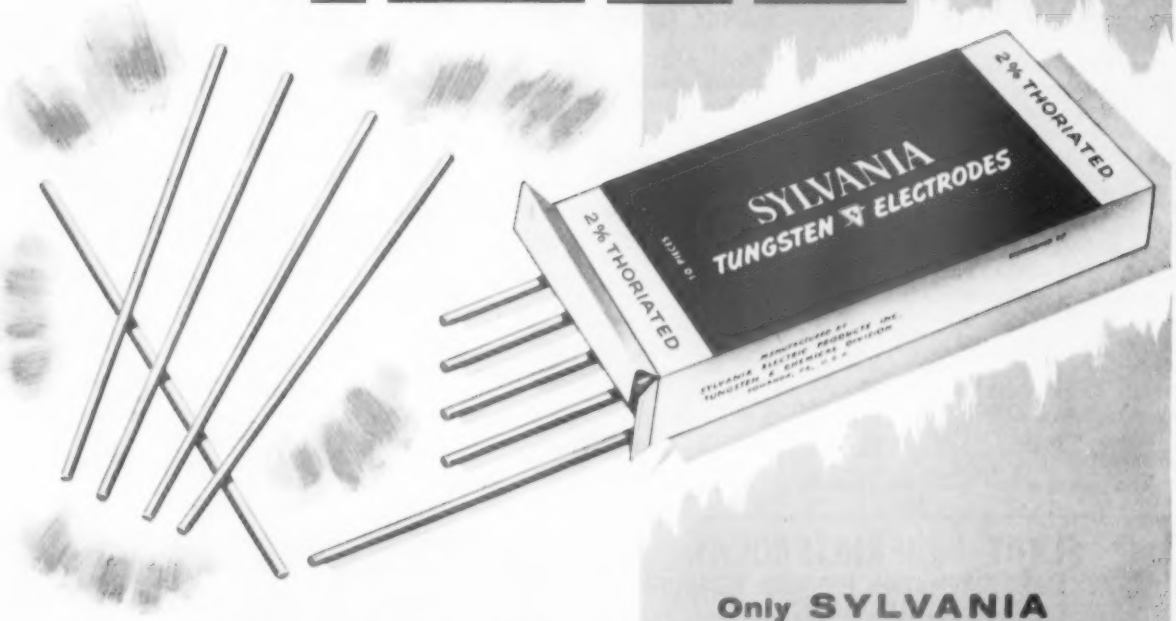
Los Angeles, Calif.—The *Los Angeles* Section held its regular monthly dinner meeting on Friday, September 15th at Swally's Cafe with an attendance of 100 at dinner and 114 at the meeting.

Anton L. Schaeffler AWS, metallurgist, Welding Research, of the Allis-Chalmers Manufacturing Co., Milwaukee, Wis., gave an interesting presentation of the major factors that the welder must consider when he is welding mild steel, low-alloy steel, stainless steel and dissimilar steels. Colored diagrams were used to illustrate the metallurgical changes that occur dur-

LOOKING
for a MORE economical way to rebuild worn tractor grousers?
Try
SS HI-C TRACTOR GROUSER BARS
HIGH CARBON STEEL ALLOY
• Give long wear under severe conditions at a very low cost.
• Use any good grade of low hydrogen electrode to attach.
• Also easy to attach by almost any automatic welding method.
Write for Details and Price List
ORDER THROUGH YOUR NEAREST MANGANAL DEALER
STULZ-SICKLES CO.
SOLE PRODUCERS 92 N. J. RAILROAD AVE. NEWARK, N. J.
NEAREST DISTRIBUTOR UPON REQUEST

They're here!

NEW 2% THORIATED
Sylvania Tungsten Electrodes
...at lowest cost ever!



If tungsten inert gas welding is one of your shop's operations—here is good news for you!

Sylvania's new 2% Thoriated Tungsten Electrode is here . . . *at a lower price than you have been accustomed to paying for similar electrodes.*

For specific applications Sylvania 2% Thoriated Tungsten Electrodes give you easier arc starting, more stable arc, higher current capacity, longer life and increased resistance to weld pool contamination.

Remember . . . there is a *right* Sylvania electrode for *every* job. Your Sylvania welding distributor will gladly recommend the correct electrode. Be prepared for any job by ordering some of each type. For technical information, write to:

SYLVANIA ELECTRIC PRODUCTS INC.
1740 Broadway, New York 19, N. Y.
In Canada Sylvania Electric (Canada) Ltd.
University Tower Bldg., Montreal, P. Q.

Only SYLVANIA has the complete line of tungsten electrodes–

- **Puretung**
- **Zirtung**
- **Thoriated**
- **2% Thoriated**

SYLVANIA

Lighting • Radio • Electronics • Television • Atomic Energy

ing welding. The principles of welding dissimilar metals were outlined. Mr. Schaeffler spoke of the changes that transpire during a multiple pass weld. He explained the conditions present in austenite, pearlite, ferrite and martensite structures. Mr. Schaeffler concluded his talk by recommending that everyone present have a copy of the Second Edition of *Welding Metallurgy*.

Two door prizes provided by Victor Equipment Co. were awarded to people attending the meeting.

AIRCRAFT AND ROCKETRY PANEL

Los Angeles, Calif.—The first meeting of the *Aircraft and Rocketry Panel* of the *Los Angeles* Section for the current season was held on September 1st at Swally's Cafe.

The program for the evening was presented by John Ross [illegible], industrial sales manager of Handy and Harman, Los Angeles, with which company Mr. Ross has been associated in an executive capacity for the past 17 years. Mr. Ross' paper, entitled "New Horizons for Brazing," dwelt on high-temperature brazing, the materials and fluxes required and the type and use of atmosphere-controlled furnaces required for various brazing processes.

The program was quite timely and held great interest for those in attendance as it ties in closely with recent missile and rocket development and the fabrication of honey-comb-type core structures.

Mr. Ross also dwelt on the use of brazing processes for the fabrication of light gage stainless steel skins for future aircraft.

Following the paper on "New Horizons for Brazing," an interesting 16-mm picture in sound and color was shown entitled "Living Silver," covering the fabrication of hollow ware articles of sterling silver.

PANEL OFFICERS

Los Angeles, Calif.—The newly elected officers for the Aircraft and Rocketry Panel of the Los Angeles Section are as follows:

Chairman—H. L. Meredith, North American Aviation Inc.
Vice - Chairman—Mario Ochieano, Lockheed Aircraft Co.
Secretary—Leo West, Douglas Aircraft Co.
Membership Chairman—Arnold Jensen, Pacific Metals Co.
Past-Chairman and Director-at-Large—R. C. Hayes, 906 Floral Drive.

STEEL CASTINGS

Madison, Wis.—H. R. Bergmann of the Falk Corp., Milwaukee, was the guest speaker at the September 22nd dinner meeting of the *Madison* Section held at the Eagles Club. He presented an excellent talk on "Steel Castings—Their Engineering Advantages in Weldments."

Through the courtesy of the University of Wisconsin, an excellent movie entitled "The Story of Tin From Bolivia," was shown prior to the meeting.

MADISON PROGRAM

Madison, Wis.—The program for the remainder of the 1955–56 season of the *Madison* Section is given below. The regular meetings will be held at the Eagles Club.

Thursday, Jan. 26, 1956—"Prevention and Control of Distortion in Welding," by La Motte Grover.
Feb. 22–24, 1956—Welding Institute.
Thursday, Feb. 23, 1956—"Better Welding at Lower Cost," by Lewis Gilbert.
Thursday, Mar. 22, 1956—"Importance of Metal Spraying," by C. J. O'Boyle.
Thursday, Apr. 26, 1956—"The Value of Nondestructive Testing in Welding," by R. O. Schiebel, Jr.
Thursday, May 24, 1956—Social Meeting.

PLANT SUPERINTENDENT

HEAVY STEEL FABRICATION PRESSURE VESSELS—HEAT EXCHANGERS

Experienced person of mature judgment required to supervise all aspects of shop fabrication consisting of heavy steel, stainless, nickel, etc., miscellaneous welded fabricated products.

Knowledge of ASME, API, and similar codes as well as general machining operations required.

Long actual working experience on welding, fitting, layout and press work as well as similar supervisory background essential. Must have thorough knowledge of materials and man hours.

This is a well paying career opportunity in pleasant medium size engineering and manufacturing company located in Metropolitan New York area. All replies will be held in strict confidence. Send full resume to Box V-328.

UNITED STATES TESTING COMPANY, INC.

INSPECTION and TESTING of Welding and Weldments

QUALIFICATION of Procedures and Operators

Main Laboratories . . . . . Hoboken, N. J.

Boston Philadelphia New York Los Angeles Dallas
Providence Wilmington Memphis Denver

WOULD YOU LIKE THE **FACTS?**

WESTINGHOUSE ELECTRIC CORPORATION
Welding Dept., Box 868
Pittsburgh 30, Penna.

☐ Send all information, FREE samples new Westinghouse SW-3 electrode.
☐ Have welding specialist call.

NAME _____ TITLE _____
COMPANY _____
STREET & NO. _____
CITY _____ ZONE _____ STATE _____

SEND TODAY for free information on . . .

NEW WESTINGHOUSE SW-3 ELECTRODE

Out of our progressive electrode development labs has come another great E-6013 electrode—Westinghouse SW-3.

It will speed your weldment production—especially skip and tack, yield 5 to 20 percent more fillet footage, weld in all positions. You'll be amazed at its fast metal spread and slag balance, its easy manipulation on poor fit-ups. No burning through. No undercutting.

Try this great new Westinghouse electrode. Fill out the above coupon now. J-21920

YOU CAN BE SURE...IF IT'S **Westinghouse**

NO SINGLE WELDER WILL DO IT ALL!

THERE'S EXACTLY
THE RIGHT **miller** WELDER
TO MEET EVERY WELDING REQUIREMENT

MILLER SR RECTIFIER TYPE DC ARC WELDERS

Available in 200, 300, 400 and 600 amperes, it is a superior direct current welder using Miller Unitran transformer control and selenium rectifiers for conversion from 3 phase AC line current. Miller SR Welders feature widest possible current range, extreme arc flexibility, maximum electrode deposition rate and highest electrical efficiency.

THE *New* MILLER SRH RECTIFIER TYPE DC ARC WELDER

A new concept in welder design for all DC metalic arc welding. Available in 200, 300 and 400 amperes. It is ruggedly constructed, compact, and is designed to lend itself to stacking for parallel operation or to conserve floor space. It has single range control and is weatherproof.

MILLER ARC WELDERS FOR TUNGSTEN ARC WELDING PROCESS

These Miller Welders feature the patented Miller UNITRAN control circuit which combines the transformer with its own integral flux diverter. This, in conjunction with adequate open circuit voltage, high frequency, balancing resistor and optional controls insures superior uniformity and flexibility throughout the entire welding range. Available in nine models.

THE *New* MILLER MULTI ARC COMBINATION AC-DC WELDER

Available in 14 models, this new Miller Welder provides both AC and DC welding power for applications where both are required. It operates from a single phase power line and is available with high frequency and controls designed especially for inert gas arc and spot welding.

MILLER 100 SERIES HEAVY DUTY INDUSTRIAL TYPE AC WELDERS

Designed for heavy production welding and automatic welding applications. Available in eight models. The 100 Series Welders permit faster welding—as much as 35% faster. Movable coil design and 80 volts O.C.V. produces uniform and better welding characteristics throughout the entire range of the welder.

Write today for complete information on these Miller Welders.

ARC · SPOT miller GENERATORS WELDERS

miller

ELECTRIC MANUFACTURING CO., INC.
P.O. Box 798 Appleton, Wisconsin

"... if it's MILLER you know it's the finest..."

PURSELL IS GUEST SPEAKER AT NEW JERSEY SECTION

Program Chairman N. F. Kiernan *(left)*, with guest speaker R. T. Pursell

View of large audience that attended meeting

After-meeting snack and get-together being enjoyed by audience

PLANT TOUR

Baltimore, Md.—The *Maryland* Section had for their initial meeting a plant visitation to the Chevrolet Division of General Motors and Fisher Body in Baltimore, Md., on Sept. 23, 1955.

The tour took approximately one and a half hours and the members and visitors in attendance totaled one hundred and fifty.

Each department of the two companies was amply staffed with personnel to answer the many questions pertaining to the manufacture and assembly of automobiles. Plans had been made to have a photograph taken of the members in attendance but due to the inclement weather this was impossible.

At the conclusion of the tour everyone expressed their heartiest satisfaction for an evening well spent in one of the most modern and up-to-date assembly plants.

SCHEDULE OF MEETINGS

Baltimore, Md.—The *Maryland* Section presents the following meetings for the remainder of the season. All of these meetings, with the exception of May 18th, will be held at the Engineers Club, 6 W. Fayette St., Baltimore.

Jan. 20, 1956—"Automotive Welding," John Randall, Ford Motor Co.
February 17th—"Inspection of Welds," Lew Gilbert, Editor, *Industry and Welding*
March 16th—"Submerged Arc Welding," Bob Wilson, Lincoln Electric Co.
April 20th—"Welding in the Aircraft Industry," Mr. Wood, Glenn L. Martin Co.
May 18th—Installation of Officers—Banquet and Dance.

ANNUAL PICNIC

Union, N. J.—The annual picnic of the *New Jersey* Section was held on September 24th, at Old Cider Mill Grove, Union, N. J. Due to a heavy "Florida Mist" most of the activities were confined indoors and under shelters.

Six-hundred and twenty members and friends attended the picnic where they enjoyed fun, good eats and lots of beer. Contests were run off with darts, nail driving, golf putting and egg throwing. Ninety valuable door and contest prizes, donated by New Jersey firms interested in welding, were distributed, including a "Guess How Much" two-hundred and twenty nine dollar jack pot collected at the gate.

W. Apblett was Picnic Chairman.

PRESSURE PIPING

Newark, N. J.—On Tuesday, September 20th, the *New Jersey* Section held its regular monthly dinner meeting at the Essex House.

ANNUAL PICNIC HELD BY NEW JERSEY SECTION ON SEPTEMBER 24

Bill Apblett, Picnic Chairman, shown with door and contest prizes

Ernie DiLiberti *(center)* presenting one of the door prizes

Chairman Apblett presenting Messrs. Jurick and Purron with jars of gate prize money

Nail driving contest proved very popular. Here contestant gives it a try

Fun and laughter were the order of the day. Egg throwing contest was a "Smash"!

NEW ALL POSITION IRON POWDER ELECTRODE

Welds like Jetweld
DOWNHAND

Welds like Fleetweld
VERTICAL & OVERHEAD

Improved

FLEETWELD 47

faster, smoother, easier to handle

TRY IT!

THE LINCOLN ELECTRIC COMPANY
Dept. 1909, Cleveland 17, Ohio
The World's Largest Manufacturer of Arc Welding Equipment

Program Chairman N. F. Kiernan introduced the speaker for the evening, Robert T. Pursell. His subject was "Joint Detail for Inert Arc Welding of Pressure Piping." Mr. Pursell is now metallurgical engineer for Stone and Webster Engineering Corp., a graduate of Newark College of Engineering and author of several publications on welding and radiography.

Mr. Pursell illustrated by slides and pipe joint samples a unique method for welding pipe joints without the use of metallic backing rings, using an inert-gas atmosphere inside the pipe and held within the joint area by consumable paper disks sealed by masking tape. The inert gas is inserted through a small hole in the welding groove. Visual inspection of the inside weld was made with the use of an Aemi Boroscope inserted through the same hole used for the gas backing.

The question and answer period was conducted by Vice-Chairman L. T. Detlor. This was followed with the usual refreshment and social get-together.

One hundred and ten attended the technical meeting.

ALLOY STEELS

New York, N. Y.—"Suitability of Quenched and Tempered Steels for Pressure Vessel Construction" was the subject of the paper presented to the *New York* Section on September 13th. Leon Bibber, chief research engineer for the United States Steel Corp., Pittsburgh, Pa., was the speaker. Mr. Bibber gave a very comprehensive lecture on the unusual qualities of the recently developed Commercial Armor Plate material in the operation "T-1".

The toughness of this material under severe low temperature was demonstrated at the Chicago Bridge & Iron Co.'s Plant in Birmingham, Ala., where 8 tanks, 48 in. in diameter and 20 ft long, had been built and were tested to destruction. Film showing this test clearly indicated the durability of the material. Four of the tanks were destroyed by bursting them after they had been filled with a brine solution of calcium chloride and dry ice, and chilled to approximately −45 deg. The remaining four tanks were tested by impact while under 900 lb internal pressure and at −45 deg temperature. The bursting pressure reached was 2000 lb and the impact load on the tanks, resting on two saddles, was 26,700 lb dropped from a height of 105 ft.

Mr. Bibber also showed a series of slides giving chemical composition of the material and accumulated test data.

The meeting was indeed a very interesting one and beneficial to everyone present.

WELDING STAINLESS STEEL

Buffalo, N. Y.—J. A. Goodford, chief welding engineer of the Crucible Steel Co. of America, Paterson, N. J. was the speaker at the September 22nd dinner meeting of the *Niagara Frontier* Section held at the Sheraton Hotel.

Mr. Goodford delivered an excellent talk on "Welding of Fabricated Stainless Steel Products and Stainless Steel Castings."

The meeting was well attended for the first meeting of the season, and there was quite an extensive question and answer period following the paper and slides.

SUBMERGED ARC WELDING

Marion, Ohio—The *North Central Ohio* Section got off to a good start with 56 members and guests at their first dinner meeting of the season which was held on September 9th at the Hotel Harding. The Section was very happy to have as coffee speaker Joe Magrath, National Secretary.

Speaker at the technical meeting was Frank Boucher of the Lincoln Electric Co., Detroit, Mich. His talk on "Applications of Submerged Arc Welding" was very well received and of much interest to all.

Through the courtesy of the Metallizing Engineering Co., a film on metallizing was shown before the meeting.

WELLAUER ADDRESSES NORTHWEST SECTION

New Chairman Charles M. Clogston (*left*) and new Vice-Chairman A. P. Demmer (*right*) of the *Northwest* Section trade postdinner conversation with E. J. Wellauer of Falk Corp., Milwaukee, Wis., before his illustrated talk before members on "Uses of Steel in Steel Foundries and Design of Cast Steel Castings for Weldments," Monday, September 12th, in the Lodge Room of the Covered Wagon.

MEETINGS PROGRAM

Marion, Ohio—The meeting dates and locations of meetings of the *North Central Ohio* Section for the remainder of the season are as follows:

Jan. 6, 1956—Marion.
Feb. 3, 1956—Marion.
Mar. 2, 1956—Plant Visitation, Gar Wood Industries, Findlay, Ohio.
Apr. 21, 1956—Second Annual Ladies Night, Mansfield, Ohio.
May 4, 1956—Lima.

At all technical meetings, the dinner will be followed by a half hour long movie, then the feature speaker and then a question and answer period.

WELDING SHOW

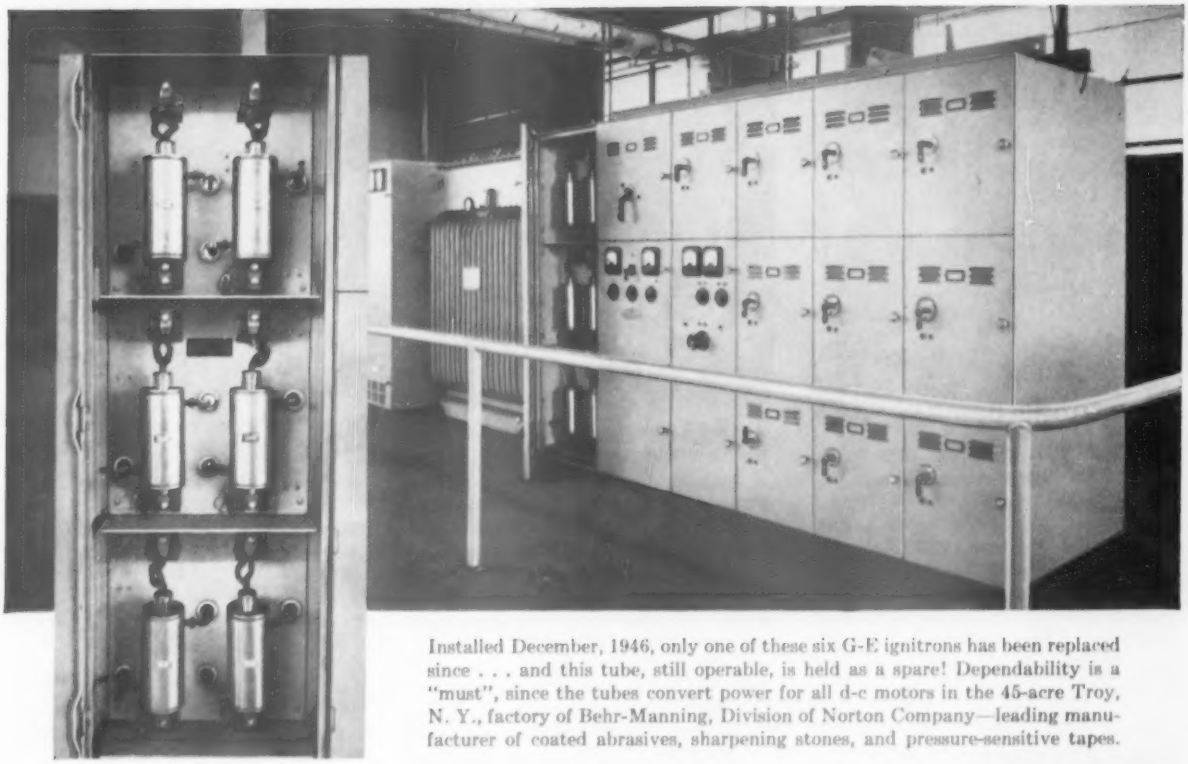
Northwest Chairman Charles M. Clogston of Northern Ordnance, Inc., John Markwell of Dunwoody and Roger Griffis of H. R. Toll Welding Equipment and Supply Co. were in charge of this second successful annual show for tradesmen, students, mechanics and suppliers, attended this year by two thousand people, September 19th and 20th.

John Markwell, *Northwest* Section member and welding instructor at Dunwoody Industrial Institute, Minneapolis, explains new oxygen cutting equipment to students Siswanto, (*left*) and Pratomo (they have only one name) of Indonesia at a welding show sponsored jointly by Dunwoody Institute and the Northwest Section of the American Welding Society. Siswanto and Pratomo are students attending Dunwoody under a grant from the Ford Foundation.

ERIE PROGRAM

Erie, Pa.—The schedule of meetings for the *Northwestern Pennsylvania* Section for the remainder of the season is given below:

Jan. 24, 1956—"Welding Metallurgy," by G. E. Claussen, Metals Research Laboratory Linde Air Products, Niagara Falls, N. Y.



Installed December, 1946, only one of these six G-E ignitrons has been replaced since . . . and this tube, still operable, is held as a spare! Dependability is a "must", since the tubes convert power for all d-c motors in the 45-acre Troy, N. Y., factory of Behr-Manning, Division of Norton Company—leading manufacturer of coated abrasives, sharpening stones, and pressure-sensitive tapes.

5 G-E ignitrons in this Behr-Manning installation have been in full-time service for 9 years!

YOU buy dependability and long life when you invest in General Electric ignitrons. These qualities pay off in minimum maintenance and rock-bottom replacement costs.

Behr-Manning, for example, has not had to purchase a new ignitron for power conversion since 1946. The single replacement tube used in the past nine years was already on hand, being one of two extras bought for protective inventory at time of installation.

Your local G-E tube distributor delivers this same money-saving ignitron quality to your plant. And he has the exact types you need for your power-conversion, welding, or other equipment.

Four G-E standard ignitrons for power rectification range from 40 amp average current up to 350 amp. There are five G-E Temperature-controlled rectifier ignitrons, from 40 amp up to 400 amp.

For welding, G.E. makes available three popular and widely-used ignitrons—40-amp, 140-amp, and 355-amp. All have provision for temperature-control attachment, and are supplied with this when desired.

In addition, these same welder tubes can be obtained with G.E.'s built-in temperature control, outstanding for water economy and protection against burnout.

Phone your G-E distributor on any and all ignitron problems! He has top-quality tubes . . . the right types . . . at fully competitive prices. *Tube Department, General Electric Company, Schenectady 5, N. Y.*

Progress Is Our Most Important Product

GENERAL ELECTRIC

161-183

Feb. 28, 1956—"Weld Metal Cracking and Flaws," by P. J. Rieppel, chief and R. P. Sopher, assistant, Metals Joining Laboratory, Battelle Memorial Institute, Columbus, Ohio.

Mar. 27, 1956—"CO_2 Shielded Consumable Electrode Arc Welding," by G. R. Rothschild, Research Laboratories, Air Reduction Co., Murray Hill, N. J.

Apr. 24, 1956—Plant Visitation, Bucyrus-Erie.

May 22, 1956—Annual Business Meeting.

WELDING PROCEDURE DESIGN

Philadelphia, Pa.—The first meeting of the *Philadelphia* Section of the new season was held at the Drexel Institute of Technology on September 19th. The meeting was held in conjunction with Drexel to inaugurate the third season of the Philadelphia Section sponsoring a course in welding education. Full details are given in the "Society News" section of this issue.

NONDESTRUCTIVE TESTING

Portland, Ore.—The September 13th dinner meeting of the *Portland* Section was held at the Heathman Hotel. Speaker was Richard P. Turner of the Magnaflux Corp., Los Angeles. His subject was "Nondestructive Inspection of Welds."

INERT-ARC WELDING

Seattle, Wash.—The *Puget Sound* Section held its regular monthly dinner meeting on September 8th at the Engineer's Club. "Inert Gas Welding of Carbon Steel Pipe" was the subject of an excellent talk given by F. J. Pilia of Linde Air Products.

MACKINAC STRAITS BRIDGE

Saginaw, Mich.—The September 8th meeting of the *Saginaw Valley* Section was held at the High Life Inn.

Coffee speaker was Ralph I. Blouch, game biologist for the Department of Conservation. Mr. Blouch spoke on the rules, regulations and general conditions of game in the state of Michigan.

After a short intermission, Chairman Woollard introduced the main speaker of the evening Orlando Doyle of Merritt-Chapman & Scott. Mr. Doyle is employed as chief field engineer on construction of foundations of the Mackinac Straits bridge. He presented slides and discussed the complete construction of the bridge piers in detail, especially the underwater structure. The bridge is a complete welded unit and therefore of interest to the WELDING SOCIETY. The bridge is not rigid but capable of swaying under wind pressure. Mr. Doyle told of the setbacks encountered when hoisting with cranes and of how the welds did not break even under such terrific stress, and of how iron was torn, but the welding held. He discussed the different types of piers: box type and round type; piers of 85–86 ft diam made of steel and concrete using a special process; alignment of piers and methods used. He told of the immense job of hauling high sections to the Straits; of driving tubes into mud, getting into rock formation and scooping mud out of the drums with crane buckets. He told of the surveyors and their work of pinpointing the exact location for these piers and the time needed and taken for this work. Special machines were built for driving steel piling to locate precisely in the center of steel piers so that there would not be a possibility of driving one steel pier on top of another. Mr. Doyle remarked about the minimum loss of life considering the immensity of the job and of meeting schedules on time. A comparison was made between the men of pioneer days and the men of today—as an eye witness Mr. Doyle tetified that today's men did not have to take a back seat as shown by the stamina of the men who worked for him. The slides and talk presented by Mr. Doyle proved most interesting to all.

SAGINAW VALLEY SECTION HEARS DOYLE AND BLOUCH

"Coffee Speaker" Ralph I. Blouch discussing game situation

Orlando Doyle delivering principal address dealing with Straits Bridge

SAGINAW MEETINGS

Saginaw, Mich.—Meeting dates and subjects for the remainder of the season of the Saginaw Valley Section are given herewith:

February 11th—Dinner-Dance, Rolling Green Country Club, Saginaw.

March 15th—"Aspects of Welding Metallurgy."

April 12th (Tentative)—"Use of Electronic Controls on Machine Sequencing of Resistance Welding Equipment."

May—Symposium.

All dinner meetings will be held at the High Life Inn.

OFFICERS MEET

Oakland, Calif.—New Officers and committee chairmen of the *San Francisco* Section met Aug. 4, 1955, at the Bow & Bell, Jack London Square, Oakland, Calif., for dinner and discussion of plans for the coming season. Two of the photos taken at this meeting are shown on the next page.

WELDING METALLURGY

San Jose, Calif.—The September dinner meeting of the *Santa Clara Valley* Section was held on September 20th at the Hawaiian Gardens in San Jose.

Technical speaker was Anton L. Schaeffler [illegible], Metallurgist Welding Research, Allis-Chalmers Manufacturing Co., Milwaukee, Wis. Mr. Schaeffler gave an excellent talk on "Simplified Metallurgy for Welders and Welding Supervisors." He discussed the major factors that the welder must consider when he is welding mild steel, low-alloy steel, stainless steel and dissimilar steels. Colored diagrams were used to illustrate the metallurgical changes that occur during welding. Fundamental

AT THE AUGUST MEETING OF SAN FRANCISCO SECTION

Leaders of San Francisco Section Map Strategy for 1955–1956 Season: Seated (*left to right*): Technical Chairman S. D. Roberts, of San Francisco Naval Shipyard; guest Mr. Wylie, of California Polytechnic Institute; Membership Chairman Cecil W. Doggett, of Linde Air Products; Treasurer B. P. Faas, of Standard Oil Co. By-Laws Chairman C. M. Leach, of Grove Controls; Public Relations Chairman Frank W. Leavitt, of Southern Pacific Railroad; Publications Chairman P. J. Joyce of Metal & Thermit; Second Vice-Chairman Fred Stettner, of Victor Equipment Co.

Standing (*left to right*): Reception Chairman Don Rowen, of Air Reduction Pacific Co.; Secretary Lawrence Robbins, of Mare Island Naval Shipyard; Chairman C. B. Robinson of Air Reduction Pacific Co.; and Past-Chairman L. A. Kech, of Kaiser Steel.

1955–56 Officers of San Francisco Section: Seated (*left to right*): Lawrence Robbins, Secretary; C. B. Robinson, Chairman. Standing (*left to right*): B. P. Faas, Treasurer; Fred Stettner, 2nd Vice-Chairman.

principles of welding dissimilar metals were outlined.

An added feature was a coffee talk by Carroll Carlton of Birdsell Manufacturing Co., Los Altos, who gave a brief talk on "Automation in the Welding Field."

SURFACING

Miami, Fla.—The first meeting of the second year of the *South Florida* Section was held on Wednesday, September 21st, at the Republican Club, Miami.

The meeting was called to order by outgoing Chairman Tom Berg, who thanked all the officers and committee members of the past year for their excellent cooperation in making this new Section a success.

The meeting was then turned over to the new Chairman Al Thompson who expressed his appreciation for a job well done by the Chairman during the past year and presented Tom with a Past-Chairman's Pin.

Guest speaker was Robert Bramley AWS, Sales Manager of Stulz Sickles Co., Newark, N. J. Mr. Bramley's subject was on Manganese-Nickel Hard Surfacing. A question and answer period was held and some very interesting questions were satisfactorily answered. It was a most instructive and interesting subject to all.

AUTOMATIC PROCESSES

Syracuse, N. Y.—The first fall dinner and technical meeting of the *Syracuse* Section at the Hotel Onondaga in Syracuse, N. Y., was started promptly at 6:30 o'clock with a good dinner.

The coffee speaker, Warren Pease, vice-president of the Syracuse Savings Bank, gave a very interesting and educational talk on various phases of banking. When he stated that the primary interest of his organization was to lend money, he could have set himself up in business on the spot if the reaction of the members present was any indication.

The technical meeting speaker was Harley Orr AWS, electrical engineer for Hobart Bros. Co., Troy, Ohio, whose subject was "Constant Voltage Applications to Automatic Welding Processes."

His talk was accompanied by slides which showed typical installations of constant potential equipment employing the inert-gas-shielded metal-arc and the submerged-arc processes.

The general discussion of procedural details employing the constant potential welder was very interesting and informative.

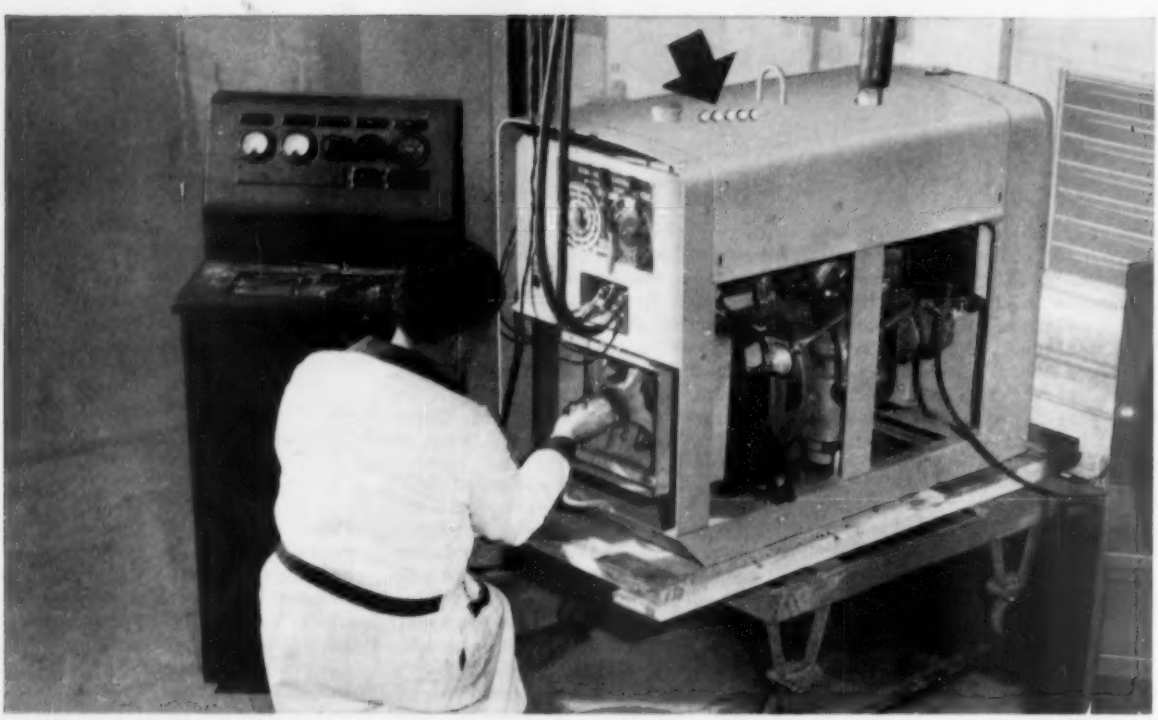
Mark Your Calendar, Now for **MAY 8–11, 1956**

FOURTH AWS WELDING SHOW

Statler Hotel, Buffalo, N. Y.

National Spring Meeting and 37th Annual Meeting

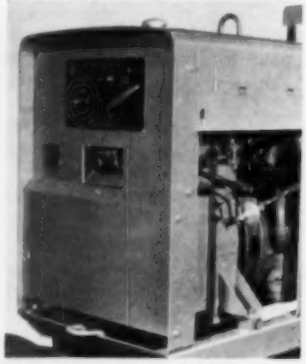
NOW! Steady Output



5 NICKELS STAND ON END while the new G-E 200-amp welder runs at full load. This unusually steady operation demonstrates the advanced engineering thought which makes the G-E engine-drive welder your best performance buy.

PROVE IT TO YOURSELF— Make this actual feature-by-feature comparison of the new 200-amp G-E engine-drive welder with two other welders of the same rating. You will see that only the new G-E welder has so many advanced design features for better welding performance at lower cost.

ELECTRODE SELECTOR, CURRENT DIAL—Dual controls simplify current control, give you easier, more accurate adjustment.



NON-PROJECTING GENERATOR—No vital parts are exposed. Full-length base encloses generator for rugged in-the-field welding.

PUSHER ENGINE FAN—Air is blown out of radiator, helping to prevent vapor lock.

GENERAL ELECTRIC	✓	✓	✓
MANUFACTURER A			✓
MANUFACTURER B			

Hour After Hour, at Full Load

...WITH GENERAL ELECTRIC'S ALL NEW 200-AMP ENGINE-DRIVE WELDER

General Electric's new 200-amp engine-drive welder eliminates one of the welding operator's common complaints—excessive loss of amperage and arc heat when operating the welder at full load for a sustained period.

This powerful welder is equipped with a direct-connected Hercules engine and specially designed generator. This combination maintains steady output and 100% arc stability—hour after hour—even when operated above full load. And no matter what type or size of electrode you use, or where you set the controls, this G-E welder provides complete freedom from "pop-outs." This is due to the high recovery voltage of the welder.

Six months of rigorous in-the-field testing by 18 pipeline welding operators has already proved that the new G-E engine-drive welder has that extra punch needed for top performance in job shops, on construction, and similar welding operations.

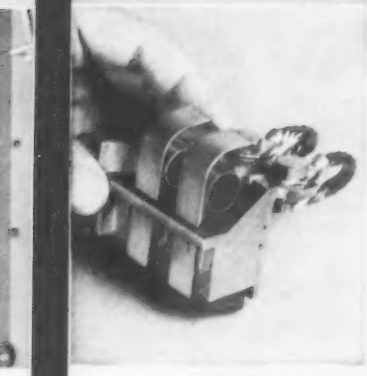
Only the new G-E welder has so many features that assure superior welding. With "rugged simplicity" built in, the G-E welder has fewer parts, sturdier construction for longer life.

Check below to see how this welder compares with other make welders, feature by feature. Then make your own test.

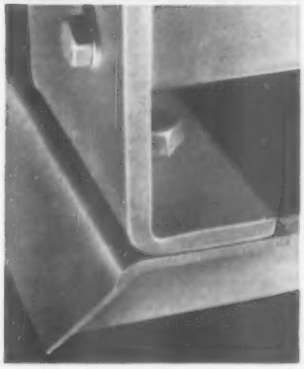
For more information, write for bulletin GEC-1333, Section 714-1, General Electric Company, Schenectady 5, New York, or contact your nearby G-E Welding Distributor. He's listed in the yellow pages of your phone book. And ask him also about General Electric's new special electrodes for construction—W-610A and W-710A. 714-1

Progress Is Our Most Important Product

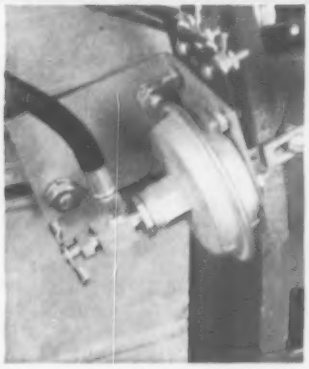
GENERAL ELECTRIC



CONSTANT PRESSURE BRUSH SPRINGS—New feature eliminates need for adjustment.



HEAVY-GAUGE METAL THROUGHOUT—16-gauge canopy, 3/16-in. channels, 1/4-in. cross bars withstand rough field conditions.



OVER 12-HOUR OPERATION—New slowdown control and 17-gallon tank give more than one shift operation on a tank of gas.

SPRING-WOUND TRAILER AXLE—New construction of axle reduces side sway and weaving for easier towing, better tracking.

New Members

Effective September 1, 1955

MEMBERSHIP CLASSIFICATION

A—Sustaining Member B—Member C—Associate Member D—Student E—Honorary Member F—Life Member

ALBUQUERQUE

Johnson, Frederick W. (C)

ARIZONA

Stickney, Jerome (C)

BIRMINGHAM

Bertorsa, Donald C. (C)
Capp, Craig T. (C)
Easter, J. S. (B)
Floyd, Walter M. (C)
O'Connell, Joseph F. (C)
Price, J. D. (B)
Sangdahl, G. S. (C)

BOSTON

George, Frank (C)

CHICAGO

Arne, Christian (B)
Butler, S. (B)
Coffey, David (B)
Cracco, Victor J. (C)
Frandsen, G. (B)
Franz, Raymond J. (C)
Harbison, Charles (B)
Hecks, C. J. (C)
Greiling, Paul R. (C)
Karns, Leslie V. (B)
Marsh, H. W. (C)
Necheles, Robert F. (C)
Rassenfoss, John H. (B)
Shaw, Charles N. (B)
Smith, Clarence J. (B)
Ward, J. S. (C)
Wickersham, William (B)

CINCINNATI

Delson, Erwin B. (C)
Koger, Byron A. (C)

CLEVELAND

Colvard, J. B., Jr. (C)
Comstock, H. H., Jr. (C)
DeCosky, Richard L. (B)
Gordon, F. J. (C)
Mannbeck, George M. (B)
McCarthy, Robert F. (C)
O'Sicka, Charles J. (C)
Rose, Otta (B)
Simmons, William V. (B)
Spino, Pat (B)

COLUMBUS

Hughes, Warren R. (D)
Meinhart, Charles (C)
Smith, Delbert R., Jr. (C)

DALLAS

Jones, Wilson M. (C)

DETROIT

Denger, Howard A. (C)
Donaldson, George (C)
English, Calvin F. (C)
Fair, Robert J. (B)
Fletcher, William (C)
Gray, Mark (B)
Graham, Dick (C)
LeBeau, Edward (B)
Roy, Raymond J. (B)
Smith, Elmer A. (B)
Taylor, Charles K. (C)
Thompson, George I. (B)
Trueman, Douglas C. (C)
Vogel, Roger R. (C)

EAST TEXAS

Frye, Elam C. (B)

FOX VALLEY

Krueger, Willard H. (C)
Mahlock, Carl (C)
Schneider, Harold (C)

HOUSTON

Albrams, Max (C)
Albin, A. C. (C)
Baur, Don H. (B)
Bonney, James C. (B)
Borg, Paul E. (B)
Buell, Sidney J. (C)
Byrd, George (C)
Cartwright, Cecil E. (B)
Crabtree, Joseph A. (B)
DeZauala, L. I. (B)
Eidson, John R., Jr. (B)
Ficken, B. A. (B)
Goldston, James M. (B)
Howard, E. A. (B)
Hubenak, J. R. (B)
Johnson, R. E. (C)
Johnson, Robert C. (B)
Jones, G. G. (B)
Kleespies, W. J. (C)
Lewis, E. C. (B)
Mackey, Raymond A. (B)
Milam, Tommy (C)
More, James J. (C)
Oglesby, R. C. (C)
Osborne, B. J. (B)
O'Shea, Joe (B)
Reeves, Tommy C. (B)
Schroeder, M. A. (B)
Shaw, C. S. (B)
Shoemaker, Lindsey (C)
Smith, Warren N. (B)
Stake, Hascall (B)
Steapp, Clyde (C)
Stephen, T. W. (B)
Stocking, Eugene E.
Vogler, Robert L. (B)
Wade, Clifford V. (B)
Wade, H. L. (B)
Walden, D. E. (C)
Walter, T. W. (C)
Waterbury, Neil A. (B)
Webb, Alto E. (B)
White, Lake (B)
Williams, Jack A. (B)
Wooldridge, William C. (B)
York, Thomas H. (B)

IOWA-ILLINOIS

Howard, Bruce A. (C)

KANSAS CITY

Ferris, Charles W. (B)
White, Thomas G. (B)

LEHIGH VALLEY

Chipser, Stephen J. (B)
Hoy, Gerald V. (C)

LONG BEACH

Miller, L. O. (B)

LONG ISLAND

Ellis, Charles W. (B)
Florio, Peter J. (B)
Hey, Henneny (B)

LOS ANGELES

Barnes, H. A. (B)
Brown, Elmer C. (B)
Kluck, Robert S. (C)

LOUISVILLE

Gumm, Peter (C)
Kolar, George (B)

MADISON

Van Horn, J. W. (C)

MAHONING VALLEY

Jones, Wendell D. (C)
Mikel, William (C)
Smith, Ford E. (B)

MICHIANA

Mott, Robert C. (C)

MARYLAND

Meyer, Christian J. (C)
Wood, David H. (C)

MILWAUKEE

Bulson, Lester C. (C)
Sheperd, Erwin M. (B)
Skowronski, John S. (B)

NEW JERSEY

Gerwin, Edward F. (B)
Hackman, Robert L. (B)
Hoffman, Charles W. (C)
Hoshowsky, Harry G. (B)

NEW YORK

Boggs, Robert W. (B)
Clark, John L. (B)
Ewalt, Newton (B)
Oberg, James L. (B)
Outcalt, Frederick G. (B)
Phillips, Arthur L. (B)
Vanick, James S. (B)
Weishoff, Samuel (B)
Tippett, J. M. (C)

NIAGARA FRONTIER

Roy, John R. (C)

NORTHWEST

Ester, E. C. (C)
Tellander, W. H. (C)
Wallace, G. V. (C)

NORTHWESTERN PENNSYLVANIA

Baker, Paul H. (C)

OKLAHOMA CITY

Hunt, J. W. (B)
Simpson, C. H. (C)

PHILADELPHIA

Bower, Charles E., Jr. (C)
Harris, L. J. (B)
Killen, W. L. (A)
Norton, Alfred S. (B)
Pollock, W. I. (C)

PITTSBURGH

Copp, Warren F. (A)
Heavey, William F., Jr. (C)
Sager, Richard K., Jr. (B)

PORTLAND

Delong, J. F. (C)
Powell, J. A. (C)

RICHMOND

Hutton, Ernest W. (B)
Jenkins, William B. (B)
McGowna, Haywood (C)
Rapp, Howard C. (D)

ROCHESTER

Erdle, Jack A. (C)

SAGINAW VALLEY

Schmoak, Ralph K. (C)

***Sureweld*® A-C SHOP WELDERS**—For general repair and light production work. 3 models.

Sureweld **A-C INDUSTRIAL WELDERS**—For heavy duty production welding. 9 models.

Sureweld **Gasarc A-C WELDERS**—For tungsten electrode inert-gas welding. 5 models.

Sureweld **D-C RECTIFIER ARC WELDER**—For manual and automatic welding—tungsten or metal electrode inert-gas welding.

Sureweld **PORTABLE D-C ARC WELDER**—Gas driven welder for field welding and maintenance work.

Sureweld **CONSTANT POTENTIAL WELDER**—For automatic or semi-automatic welding—metal electrode inert-gas or submerged arc welding.

Before you buy any welder... Examine the NCG® line...and compare

Are you in the market for a welder? Whatever the type you need, whatever the capacity, be sure to see the NCG *Sureweld* line. Each type of *Sureweld* welder has superior features that distinguish it from other makes . . . features you'll like, features your operator will like. Check the design, the construction, the performance, the easy operation, the power consumption. Ask for names of *Sureweld* users in your locality. Find out what kind of performance *they* get.

Call your NCG dealer or nearby NCG office for the facts about *Sureweld* welders . . . about operating ease, performance, costs. Or write for literature to the address at the right.

NCG®

EVERYTHING FOR WELDING

NATIONAL CYLINDER GAS COMPANY

840 N. Michigan Avenue
Chicago 11, Illinois

Branches and Dealers from Coast to Coast

Copyright 1958, National Cylinder Gas Company

ST. LOUIS

Davis, A. W. (C)
Geoghegan, William M. (C)

SALT LAKE CITY

Clarence, William (C)
Despain, Wayne (C)
Loveless, Gordon R. (B)
Muir, Earl (C)
Oscarson, George (C)

SAN FRANCISCO

Dada, Edwin T. (C)
Lamb, George A. (C)
Peterson, DeWayne B. (C)

SANGAMON VALLEY

Serr, Jerome (B)

SANTA CLARA VALLEY

Sigler, Sid (B)

SOUTH FLORIDA

Bailey, E. D., Jr. (B)
Brown, William M. (B)
Richterkessing, B. T. (B)
Riley, William C. (B)
Singleton, Carlton R. (B)

TRI-CITIES

Beaver, Leslie P. (B)

TULSA

McKenzie, R. C. (B)
Prevett, J. C. (C)
Smith, C. B. (B)
Walcott, Ben E. (B)

WESTERN MASSACHUSETTS

Mobb, William S. (B)
Wilson, Thomas G. (B)

NOT IN SECTIONS

Jamison, Harry W. (B)
Russell, C. E. (A)
Mirchandani, Indersen T. (C)
Rowland, Harry C. (C)

Members Reclassified

During the month of

September

BIRMINGHAM

Clotfelter, R. E. (C to B)
Douglass, H. E. (C to B)

BOSTON

Anderson, Raymond C. (C to B)

CHICAGO

Brink, A. P. (C to B)
Meyer, Imel R. (C to B)

CLEVELAND

Lauter, Ernest H. (C to B)

DETROIT

Van Lavoeghem, Gerard (C to B)
Fox, Kenneth, A. (C to B)

HOUSTON

Joor, William E., II (C to B)
Watson, John A., Jr. (C to B)

MAHONING VALLEY

Colbert, W. D. (C to B)

NEW JERSEY

Goodford, Jack A. (C to B)

NEW ORLEANS

Reeves, E. B. (C to B)

NIAGARA FRONTIER

Rendall, William A. (C to B)

OLEAN-BRADFORD

Keyte, Jack B. (C to B)

PHILADELPHIA

Heverly, James S. (C to B)

SAN FRANCISCO

Carr, Raymond W. (C to B)

TRI CITIES

Coleman, Mills (C to B)

YORK-CENTRAL PA.

Quinn, John (C to B)
Marshall, C. B., Jr. (C to B)

Would you like the **FACTS** about . . .

WESTINGHOUSE ELECTRIC CORPORATION
Welding Dept., Box 868
Pittsburgh 30, Penna.

☐ Please send full facts about redesigned Westinghouse welders.

☐ Have welding specialist call.

NAME_____ TITLE_____
COMPANY_____
STREET & NO._____
CITY_____ ZONE____ STATE_____

Westinghouse redesigned welding machine line?

Just by filling out this coupon and mailing it to us now, you'll get all the inside facts on the newly redesigned line of Westinghouse a-c, d-c and RMC (a-c—d-c) welders.

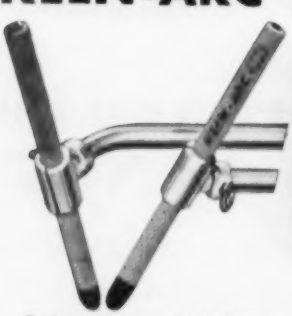
You'll read about how the CONTINUOUS arc drive means faster production at less cost; how new thermal overload protection device minimizes down time, ups total output.

J-21921

YOU CAN BE **SURE**...IF IT'S
Westinghouse

BECKER

KEEN-ARC CARBONS



FOR CONSISTENTLY GOOD RESULTS

Designed to carry the high currents necessary for intense heat, BBB Keen-Arc Carbons produce a fine-grained weld of high tensile strength. They give a smooth, steady "flowing" flame which does not wander and which is concentrated at the desired focal point. Flame temperature is easily and accurately adjusted by merely changing the ampere input, and heavy copper coating permits gripping at extreme ends—eliminates frequent and periodic resetting.

***A COMPLETE LINE OF CARBON WELDING SUPPLIES** including carbon and graphite electrodes, carbon rods and plates, welding paste, etc.*
Write for catalog.

BECKER BROTHERS CARBON CO.
3450 South 52nd Ave. Cicero 50, Illinois

sealed in smoothness . . .
neither dirt nor trouble can enter here

Tension screw wear and sticking is a sign of poor design and inadequate manufacture—it is not necessary for you or your operator to struggle with regulator tension screw adjustment. The answer to this problem is simple—*keep foreign matter out of the threaded parts.* This tension screw is fully protected by a unique packing and a special type of friction bushing. Just try this regulator tension screw—adjust it yourself and feel how smoothly it works; you can reach maximum delivery pressure effortlessly.

this is the inside story of a wonderful improvement in tension screw design and action. No other regulator has this patented feature . . .

National of California

NATIONAL welding equipment company... 218 fremont street san francisco 5 california

52-

ABSTRACTS OF CURRENT PATENTS

prepared by Vern L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington 25, D. C.

2,716,177—Apparatus for Electric Welding—William Reid Cumming, Inverness, Scotland, assignor to Resistance Welders Ltd., Inverness, Scotland.

This patent relates to apparatus for flash butt welding the surfaces of two metal workpieces. The apparatus includes a pair of carriages movable relatively to one another and each adapted to receive a workpiece on a mounting thereon. Electric flashing current supply means are connected to the carriages and magnetic force exerting means are provided to adjust the spacing of the carriages in accordance with the electric current flowing. The magnetic force exerting means acts without time lag in accordance with variations of the flashing current to tend to maintain the flashing current constant.

2,716,689—High-Frequency Induction Seam Welding—Alfred C. Body, Cleveland, Ohio, assignor to the Ohio Crankshaft Co., Cleveland, Ohio, a corporation of Ohio.

Body's patent relates to a continuous seam-welding machine which advances a longitudinally split tube along a predetermined path, with the edges of the tube in spaced relationship and then having the two edges moved into abutting relationship at a predetermined point. The machine includes high-frequency energized inducing means disposed in advance of the point for inducing high-frequency currents to flow in the tube and between the edges at the contact point. A feature of the machine is that magnetically permeable means having a relatively high electrical resistance at least in a circumferential direction is disposed about the portions of the tube and is circumferentially spaced from the edges. This high resistance is located between at least the exit end of the inducing means and the plane normal to the axis that includes the point of initial contact of the initially spaced tube edges.

2,716,691—Method and Apparatus for Welding Tubing—Howard J. Bowman, East Troy, Wis., assignor to Trent Tube Co., East Troy, Wis., a corporation of Wisconsin.

Bowman's novel apparatus is for welding metal tubing having a longitudinally extending seam of abutting edges disposed at an angle to the horizontal. The apparatus includes means for feeding the tubing progressively past a pair of arc welding units mounted above and below the pass line of the seam. The upper welding unit mounts a nonconsumable welding electrode positioned above the center line of the seam and directed downwardly thereagainst in slightly spaced relation thereto. The lower welding unit mounts a similar electrode positioned below the center line of the seam and directed upwardly thereagainst in slightly spaced relation thereto. Each welding unit is provided with means for enveloping the welding electrodes with an atmosphere of an inert gas to be directed against the seam during welding.

2,716,692—Methods for Producing Welding Seam Tubing—Elmer W. Williams, Muskego, and Howard J. Bowman, East Troy, Wis., assignors to Trent Tube Co., East Troy, Wis., a corporation of Wisconsin.

The present patent relates to a method of welding metal tubing having a longitudinally extending seam of abutting edges. The method includes the steps of placing the tubing with the seam below the horizontal midsection of the tubing and progressively feeding the tube blank against an arc electrode disposed below the center line of the seam. Such action fusion arc welds the abutting edges together. Concurrently sufficient squeezing pressure is applied to the tube blank and to the abutting edges to impart to a resulting weld joint an inner surface substantially flush with the inner arcuate contour of the tubing, and to impart to the outer surface of the weld joint a substantially convex arcuate configuration when taking a transverse section of the weld joint.

2,717,569—Apparatus for Welding Radiators—Karl Osterman, Stockholm, and Gunnar Arnberg, Lidingo, Sweden, assignors to Svenska Aktiebolaget Gasaccumulator, Lidingo, Sweden, a corporation of Sweden.

The present patent relates to apparatus for welding together the edges of juxtaposed workpieces to provide a joint to be welded which includes at least a straight and a curved line in the plane of the weld. The apparatus comprises an elongated carriage which is pivotally supported on a frame to turn about a pivot point intermediate the edges of the carriage. Other means are provided for controlling the positioning of the workpiece, or workpieces, with relation to the welding burner to permit the desired welding action.

2,717,948—Automatic Coolant and Inert Gas Control for Inert-Gas-Shielded Welding—William S. Cockrell, San Diego, and Donald L. Heyser, Lemon Grove, Calif., assignors to the Ryan Aeronautical Co., San Diego, Calif., a corporation of California.

The subject matter of this patent relates to means for controlling the flow of inert gas and coolant in an electric-arc-welding apparatus. This apparatus has conduits for inert gas and coolant, and solenoid valves are provided in the conduits. Operating means for the valves comprise a power supply, a valve control circuit, and a time delay circuit to delay the closing of the valves after the valve control circuit is de-energized. A welding arc current control circuit is actuated by and together with the valve control circuit.

2,718,578—Spacing and Scratching Device for Stud Welding—Charles Ruebel, Lorain, and Robert W. Murdock, Bay Village, Ohio, assignors to Gregory Industries, Inc., Detroit, Mich., a corporation of Michigan.

This patent relates to a gun for welding a stud within an enclosing ferrule and includes a chuck for carrying the stud to be welded and a foot plate is provided on a leg, which leg lies wholly to one side of the stud-carrying chuck. The foot plate extends across the axis of the chuck for holding a ferrule, while scraper support means are seated against the foot. Other means hold a scraper member which is secured to the support means.

2,718,579—Stud Welding Device—George E. Kennedy, Pasadena, Calif., assignor to Gregory Industries, Inc., Detroit, Mich., a corporation of Michigan.

This patented stud welding device has a body of dielectric material and a reciprocable chuck carrier slidable in the body and adapted to be electrically connected to one side of a source of welding current. A first stud receiving chuck is positioned on the chuck carrier while a second stud receiving chuck is electrically isolated in parallel spaced relation to the first chuck and adapted to be electrically connected to the opposite side of the source of welding current. A ferrule holder is positioned to support a ferrule at the welding end of a stud carried by the first chuck and means stationarily mount the second chuck and the ferrule holder on the dielectric body.

2,718,581—Mechanism for Disintegrating Metals by an Electric Arc—Donald Thomas, Clinton, Mich., assignor to Clinton Machine Co., Clinton, Mich., a corporation of Michigan.

Thomas' patented combination includes a reciprocating mechanism, and a coolant conduit secured to and reciprocated by this mechanism. A tubular electrode is secured to and projects beyond the end of the conduit while a second tubular electrode is arranged about the first electrode in concentric spaced relation thereto. The first electrode has an opening therein for passage for coolant therefrom into the interior of the outer electrode for cooling purposes.

Current Welding Literature

ALUMINUM. Projection Welding Aluminum: How to Assemble for Lower Weight, Higher Strength, Better Performance, W. M. Stocker, Jr. Am. Mach., vol. 99, no. 15 (July 18, 1955), pp. 126–128.

ARC WELDING. Calculated Preheat Temperatures to Prevent Hard-Zone Cracking in Low-Alloy Steels, C. L. M. Cottrell and B. J. Bradstreet. Brit. Welding J., vol. 2, no. 7 (July 1955), pp. 310–312.

ARC WELDING. Economic Application of Automatic Arc Welding Equipment, J. A. Lucey. Welding & Metal Fabrication, vol. 23, no. 7 (July 1955), pp. 251–257.

BICYCLE MANUFACTURE. Automatic Brazing in Molten Salt? Industry & Welding, vol. 28, no. 7 (July 1955), pp. 46–48, 50.

BRAZING. Some Current Aspects of Industrial Brazing, J. E. Hyler. Steel Processing, vol. 41, no. 7 (July 1955), pp. 426–431, 458.

CARS, FREIGHT. New Way to Build Box Cars. Ry. Age, vol. 138, no. 26 (June 27, 1955), pp. 40–44.

CONTROLS. Automatic Arc Control, C. Bennett. Welding Engr., vol. 40, no. 7 (July 1955), pp. 34–35.

CONTROLS. Automatic Control of Machine Arc Welding, F. Hirschmann. Welding & Metal Fabrication, vol. 23, no. 7 (July 1955), pp. 262–264.

CRANKSHAFTS. Flame Hardening Large Crankshafts on Peddinghaus Machines. Machy. (Lond.), vol. 87, no. 2227 (July 22, 1955), pp. 211–212.

EDUCATION. How LeTourneau Teaches Welding, A. C. Tyler. Industry & Welding, vol. 28, no. 7 (July 1955), pp. 35–38.

GEARS. Welding Heavy Bull Gears, C. N. Aronson. Machine & Tool Blue Book, vol. 50, no. 7 (July) 1955, pp. 112–114, 116, 119–120.

HARDFACING with Oxy-Acetylene Flame, E. Ryalls. Brit. Welding J., vol. 2, no. 7 (July 1955), p. 298.

HARDFACING. New Hardfacing Process. Welding & Metal Fabrication, vol. 23, no. 7 (July 1955), pp. 265–266.

HYDRAULIC TURBINES. Fabrication of Water Turbine Components, F. Buckley. Welding & Metal Fabrication, vol. 23, no. 7 (July 1955), pp. 236–243.

INERT-GAS WELDING. Sigma Welding for Light Metals, B. R. Russell. Light Metal Age, vol. 12, no. 1-2 (Feb. 1955), pp. 10–12, 28.

IRON CASTINGS. Braze Weld Big Ones. Industry & Welding, vol. 28, no. 7 (July 1, 1955), pp. 32–34.

MAINTENANCE AND REPAIR. Reconditioning Diesel Locomotive Parts. Diesel Power, vol. 33, no. 6 (June 1955), pp. 46–49, 69.

MOTOR TRUCK MANUFACTURE. Built to Conquer Arctic. Welding Engr., vol. 40, no. 7 (July 1955), p. 31.

OXYGEN CUTTING. Fatigue Strength of Flame-Cut Specimens in Black Mild Steel, F. Koenigsberger and H. W. Green. Brit. Welding J., vol. 2, no. 7 (July 1955), pp. 313–321.

OXYGEN CUTTING. Flame Planer for Heavy Construction Work. Welding & Metal Fabrication, vol. 23, no. 7 (July 1955), pp. 260–261.

OXYGEN CUTTING. Multiple Flame Cutter Saves Machining, Grinding Costs at U. S. S. Western Metals, vol. 13, no. 6 (June 1955), p. 48.

OXYGEN CUTTING. Tooling ST-1000. Western Machy. & Steel World, vol. 46, no. 7 (July 1955), pp. 60–64.

PIPE JOINTS. Strains in Flanged Pipes, J. Y. Davie and E. J. Heeley. Brit. Welding J., vol. 2, no. 7 (July 1955) pp. 293–297.

PLASTIC WELDING Comes of Age, J. A. Neumann. Welding Engr., vol. 40, no. 7 (July 1955), pp. 42, 44.

RADIOGRAPHY of Spot Welds in Light Alloy Sheets, N. K. Gardner and E. A. Redwood. Welding & Metal Fabrication, vol. 23, no. 7 (July 1955), pp. 245–249.

RESISTANCE WELDING of High Temperature Alloys, P. M. Howard and D. Wilcox. Can. Metals, vol. 18, no. 6 (June 1955), pp. 58–62.

RESISTANCE WELDING. New Techniques for Spot-welding Aluminum, W. R. Gain. Light Metal Age, vol. 13, no. 6-7 (June 1955), pp. 19–21, 25, 27, 33.

SHIPBUILDING. Aluminium-Schiebebalken (AlMgSi), A. Szymanski. Aluminium, vol. 31, no. 6 (June 1955), pp. 271–273.

SHIPBUILDING. Economic Proportion of Welding in Shipbuilding, W. R. Mellanby. Brit. Welding J., vol. 2, no. 7 (July 1955), pp. 299–304; (discussion), no. 8 (Aug.), pp. 345–346.

SHIPBUILDING. Modern Trends in Ship Construction, R. Ellis. Welding Engr., vol. 40, no. 7 (July 1955), pp. 26–28.

SOLDERING ALUMINIUM. Engineering, vol. 179, no. 4660 (May 20, 1955), p. 639.

SOLDERING. Hard Soldering. (Aluminum). W. J. Smellie. Aircraft Production, vol. 17, no. 5 (May 1955), pp. 181–185.

STEEL STRUCTURES. Designing Cast-Weld Construction for Stainless Steel, G. L. Gibson. Am. Foundryman, vol. 27, no. 6 (June 1955), pp. 82–84.

SUBMERGED ARC WELDING. Automatic Welding in Field. Industry & Welding, vol. 28, no. 7 (July 1955), pp. 40–41, 51.

SUBMERGED ARC WELDING. Effect of Silicon in Submerged Arc Welds, W. Simon. Matls. & Methods, vol. 42, no. 1 (July 1955), pp. 132–134.

TESTING. Scope of Gamma-Radiography, L. Mullins. Brit. Instn. Radio Engrs.—J., vol. 15, no. 3 (Mar. 1955), pp. 131–141.

TITANIUM. Design Considerations for Weldable Titanium, A. S. Rose. Machine Design, vol. 27, no. 6 (June 1955), pp. 206–208.

TITANIUM. Fabricating Titanium Sheet. Metal Industry, vol. 87, no. 3 (July 15, 1955), pp. 43–45.

WELDABILITY of Cast Steels, H. Thielsch. Machine Design, vol. 27, no. 7 (July 1955), pp. 167–171.

WELDABILITY of Stainless Steel, H. Thielsch. Machine Design, vol. 27, no. 6 (June 1955), pp. 157–164.

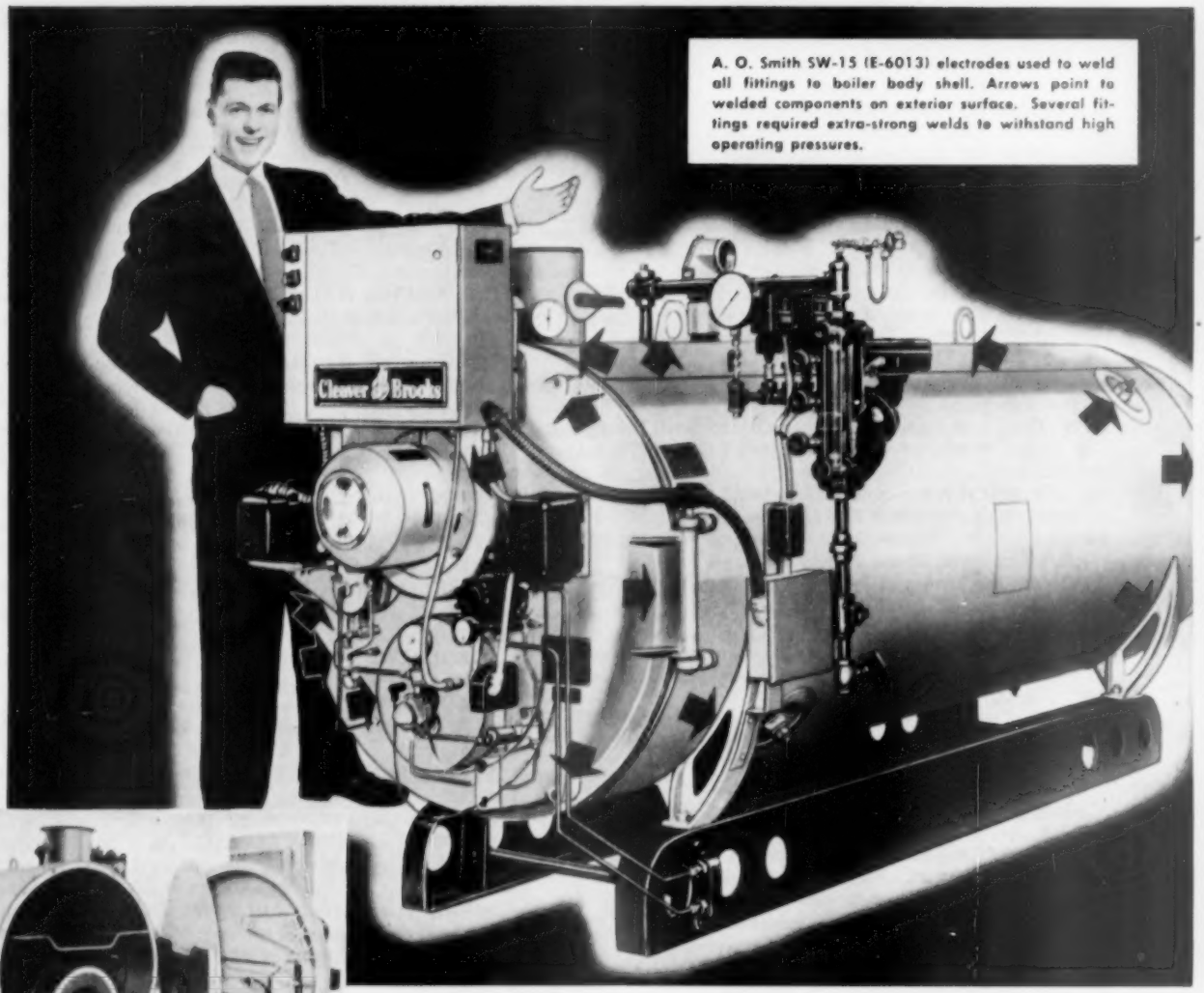
WELDING. Composition of Weld Metal, W. P. van den Blink. Brit. Welding J., vol. 2, no. 7 (July 1955), pp. 285–90; (discussion), pp. 291–292.

WELDING MACHINES. New, Automatic Carbon Dioxide Mig Welder. Welding Engr., vol. 40, no. 7 (July 1955), pp. 46, 48.

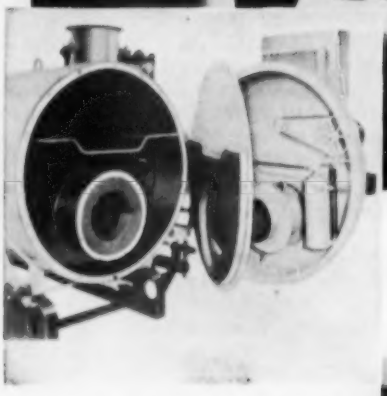
WELDING. Method for Calculating Effect of Preheat on Weldability, C. L. M. Cottrell and B. J. Bradstreet. Brit. Welding J., vol. 2, no. 7 (July 1955), pp. 305–309.

WELDING Ornamental "Iron," F. T. Tancula. Welding Engr., vol. 40, no. 7 (July 1955), pp. 29–30.

For their NEW "packaged" boiler Cleaver-Brooks

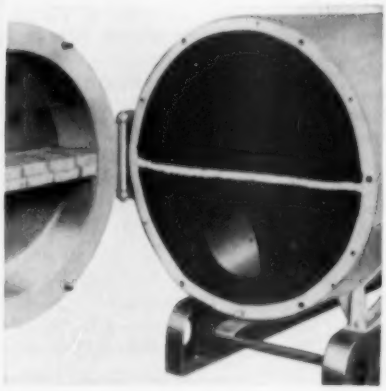


A. O. Smith SW-15 (E-6013) electrodes used to weld all fittings to boiler body shell. Arrows point to welded components on exterior surface. Several fittings required extra-strong welds to withstand high operating pressures.



A. O. Smith SW-44 (iron powder) electrodes used in welding flanges on front head (top) and rear door assemblies. Because slag peels as they weld, SW-44 electrodes virtually eliminate clean-ups.

America's top-line welding electrodes!



SW-15

Rated as the world's finest high-production electrode. Working range extends from light gauge to heavy plate. High heat and speeds can be used without risk of undercut. Operates with a quiet, even, smooth arc of medium penetration.

SW-44

A self-cleaning iron powder electrode. Ideal for all jobs in AWS Class E-6012, this weld-rod lets you deposit far more weld metal than conventional electrodes in its class. Easy re-striking — even when rod is cold.

chooses A. O. Smith electrodes for

all manual welds

A. O. Smith SW-15 and SW-44 weld-rods used for production welding of Cleaver-Brooks new "packaged" boilers

WHEN Cleaver-Brooks started production of its new, streamlined CB boilers, they selected A. O. Smith electrodes to obtain excellent welds that could meet production economies without sacrificing quality. Welds must, of course, be perfect to withstand 1½ times their design pressures, and actually they test out far in excess of ASME code requirements.

These new boilers are the result of nearly 25 years of design and manufacturing experience. Only the finest materials are used. That's why Cleaver-Brooks' engineers insisted on the A. O. Smith SW-15 electrode that produces an easily-controlled, forceful arc with deep penetration in all positions. They also specified the SW-44 iron powder electrode that's so easy to use and produces excellent beads — flawlessly smooth and practically self-cleaning.

If your products demand quality welds every time, it will pay you to buy A. O. Smith electrodes. Call your A. O. Smith distributor today, or write A. O. Smith Corporation, Welding Products Division, Milwaukee 1, Wisconsin.

The man from A. O. Smith

Roy Norton is the A. O. Smith Distributor who services the Cleaver-Brooks account. He's not only a salesman, but a welding specialist who is glad to help you with your welding problems.

PRODUCED BY WELDERS FOR WELDERS

Because welding is our full-time business, we offer you America's finest welder-proved electrodes, machines and accessories.

Through research A.O. Smith *...a better way*

A.O.Smith

CORPORATION

WELDING PRODUCTS DIVISION

Milwaukee 1, Wisconsin

INTERNATIONAL DIVISION: MILWAUKEE 1, WISCONSIN

PERSONNEL

Owings Appointed

The Miller Electric Manufacturing Co., Inc., of Appleton, Wis., has recently appointed S. B. Owings to the position of assistant sales manager.

S. B. Owings

The appointment was announced by Niels C. Miller, president of the company. Mr. Owings has been active in the electric arc welding industry for some time, and was formerly associated with National Cylinder Gas Co., Chicago, Ill.

Netch Named Manager

V. V. Netch has been named manager of Welder Sales for Vickers Electric Division, Vickers Inc., a unit of Sperry Rand Corp., St. Louis, Mo.

Mr. Netch formerly was vice-president of Hill Equipment Engineering Co., and has specialized in the welding field for the past 22 years.

V. V. Netch

C. M. "Mike" Burnett will continue in his present capacity as coordinator of dealer representatives.

New Professorship for Hechtman

Robert Aaron Hechtman, specialist in the field of structural design and former professor of Structural Research at the University of Washington (Seattle), has been appointed Professor of Civil Engineering at the George Washington University's School of Engineering. Professor Hechtman will also serve as Executive Officer of the Civil Engineering Department.

Dr. Hechtman was Research Engineer in Civil Engineering at the University of Illinois from 1945 to 1949. From 1941 to 1944 he was Structural Designer, Assistant to the Superintendent, and Administration Asst. of the Dravo Corp. An authority on problems of the structural design of ships, he has done much work in this field for the Office of Naval Research Ship Structure Committee and the National Research Council. He has authored many articles on steel and reinforced concrete structures which have appeared in publications of the Office of Naval Research, the American Institute of Steel Construction, the AMERICAN WELDING SOCIETY, and the American Society of Civil Engineers.

Dr. Hechtman is a native of Spokane, Wash., and holds the degrees of Bachelor of Science and Master of Science in Civil Engineering from the University of Washington. He received his degree of Doctor of Philosophy from the University of Illinois in 1948. He is a member of the American Society of Civil Engineers, the AMERICAN WELDING SOCIETY, the American Concrete Institute and of Tau Beta Pi (Engineering Honorary) and Sigma Xi (Science Fraternity).

Hibbard Joins Superweld

William E. Hibbard has joined Superweld Corp., North Hollywood, Calif., in the new position of Application Engineer, President R. E. Jones has announced.

A welding engineer with more than twenty years' experience in Mechanical and Metallurgical Engineering, Hibbard was a field engineer for Fabriform Metals, Los Angeles, prior to joining Superweld. Before that he spent 11 years with Bergstrom Alloys Corp., Los Angeles, in key engineering positions. While with Bergstrom he was resident engineer during the construction of Shasta Dam, and a consulting engineer to the government on the problem of setting up welding programs in government installations. He also held important posts with the Caterpillar Tractor Co., Peoria, Ill.

W. E. Hibbard

Lund Made Vice-President

Effective Sept. 1, 1955, Russell T. Lund, Operating Manager, has been appointed a vice-president of the National Carbide Co., it was announced by J. Carl Bode, president. National Carbide is a Division of Air Reduction Co., Inc.

R. T. Lund

Mr. Lund joined the Air Reduction Sales Co. Division in 1936, transferred to the National Carbide Division in 1940, and less than a year later was appointed Plant Superintendent of the Division's calcium carbide and acetylene generating plant at Louisville, Ky. On Oct. 1, 1948, he became assistant operating manager of the Division and on Oct. 1, 1949, he was appointed operating manager. He recently has devoted most of his time to the new, large calcium carbide and acetylene generating plant at Calvert City, Ky., where he will continue to make his headquarters.

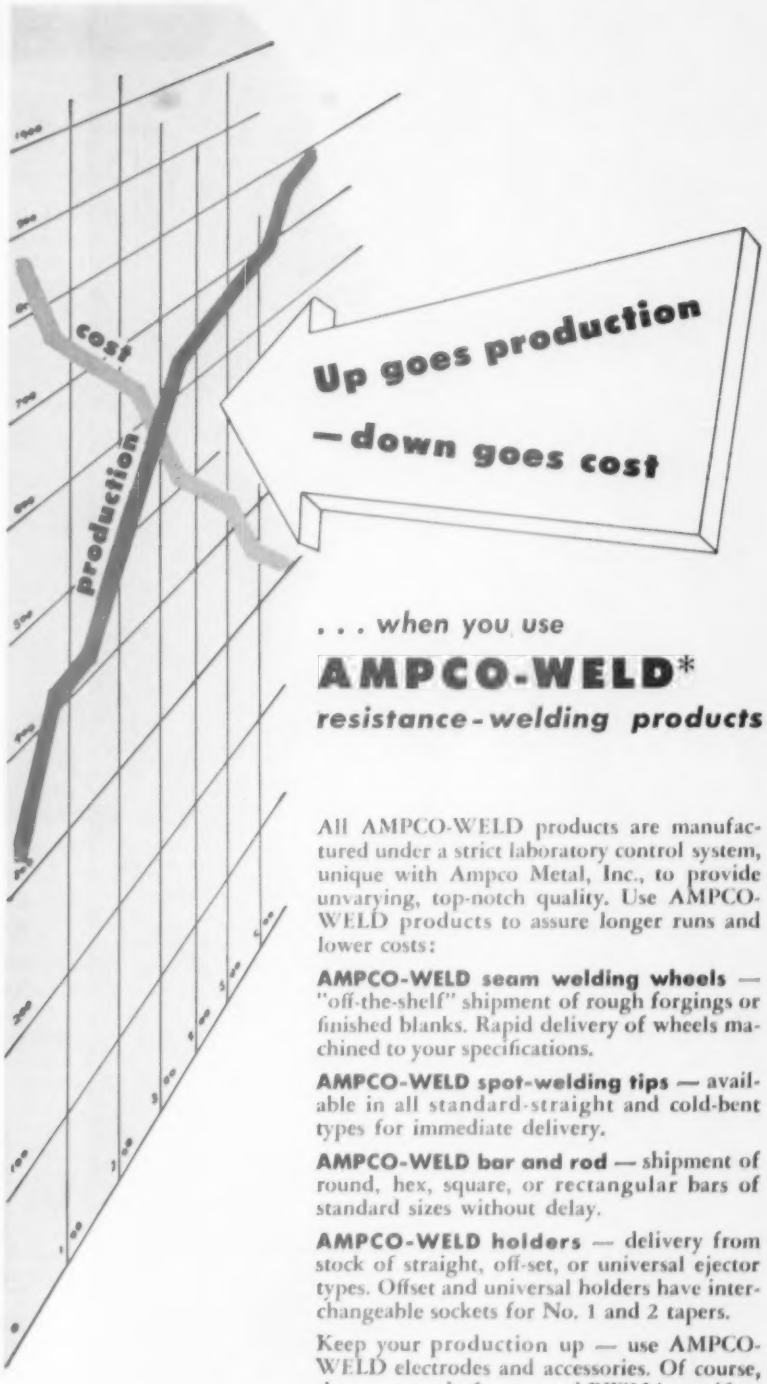
Poulson Regional Manager

John H. Poulson, Ogunquit, Me., has been appointed Regional Manager for All-State Welding Alloys Co., Inc., to cover the New England states and eastern New York state, exclusive of the metropolitan area. Announcement of his appointment was made by T. D. Nast, president, at the company's offices, White Plains, N. Y.

J. H. Poulson

Mr. Poulson will be responsible for sales and service to the users and distributors of All-State Alloys and Fluxes in his area. He will be the contact man for All-State's metallurgical resources and experimental laboratory which provide technical assistance for the solution of all manner of problems having to do with the welding, brazing, soldering, tinning and cutting of metals for maintenance, reclamation, construction and production of metal parts and equipment.

After graduating from Brown University (AB degree) Mr. Poulson studied metallography and welding, and in the U. S. Navy (1940–45) was a supervisor and instructor in these subjects. Throughout the ten years since World War II he has continued his work in the supervision, management and promotion of welding with particular emphasis on the utilization of specialty alloys.



. . . when you use

AMPCO-WELD*

resistance-welding products

All AMPCO-WELD products are manufactured under a strict laboratory control system, unique with Ampco Metal, Inc., to provide unvarying, top-notch quality. Use AMPCO-WELD products to assure longer runs and lower costs:

AMPCO-WELD seam welding wheels — "off-the-shelf" shipment of rough forgings or finished blanks. Rapid delivery of wheels machined to your specifications.

AMPCO-WELD spot-welding tips — available in all standard-straight and cold-bent types for immediate delivery.

AMPCO-WELD bar and rod — shipment of round, hex, square, or rectangular bars of standard sizes without delay.

AMPCO-WELD holders — delivery from stock of straight, off-set, or universal ejector types. Offset and universal holders have interchangeable sockets for No. 1 and 2 tapers.

Keep your production up — use AMPCO-WELD electrodes and accessories. Of course, they meet and often exceed RWMA specifications. Start specifying these dependable products today. Contact your AMPCO-WELD Distributor or write for bulletin.

*Reg. U. S. Pat. Off.

AMPCO

Sole Producer of Genuine Ampco Metal

AMPCO METAL, INC.

Dept. WJ-11, Milwaukee 46, Wisconsin

West Coast Plant: BURBANK, CALIFORNIA

RW-16

Q: Isn't all filler metal for consumable electrode welding about the same?

A: No indeed—it's the quality of the filler metal that controls the quality of the weld.

Q: How can you be sure of getting the best electrode?

A: By insisting on Alcoa's new I.G.* Electrode.

Q: Why?

A: Every production lot of Alcoa® I.G. Electrode is test welded and the welds X-rayed for soundness. Each 10-lb spool is individually packed to maintain the super-smooth finish to assure soundness of weld and smoothness of feed. Each of five alloys, 1100, 4043, 5154, 5254 and 5356 (formerly 2S, 43S, A54S, B54S and XC56S), is available in six diameters. There is no better electrode.

*inert gas

Your guide to aluminum value

I.G. ELECTRODE MADE OF
ALCOA ALUMINUM
ALUMINUM COMPANY OF AMERICA

A new, 176-page text, *Welding Alcoa Aluminum*, has just been released by Alcoa. It covers every phase of welding in complete detail. For a free copy, fill in and mail the coupon.

ALUMINUM COMPANY OF AMERICA
1741-L Alcoa Bldg., Mellon Square
Pittsburgh 19, Pa.

Gentlemen: Please send book, *Welding Alcoa Aluminum*.

Name _____

Company _____

Title _____

Address _____ City _____ State _____

Q. Where is Alcoa's new I.G. Electrode available?

A. Contact your nearest Alcoa sales office, or, for immediate delivery, call one of the Alcoa Distributors listed below. He carries a complete range of alloys and sizes, and you'll find him well qualified to work with your welding experts.

ALABAMA
Birmingham
†Hinkle Supply Co.
CALIFORNIA
Berkeley
Ducommun Metals & Supply Co.
Los Angeles
†Ducommun Metals & Supply Co.
Pacific Metals Company, Ltd.
San Diego
Ducommun Metals & Supply Co.
San Francisco
†Pacific Metals Company, Ltd.
COLORADO
Denver
Marsh Steel Corp.
Metal Goods Corp.
CONNECTICUT
Milford
†Edgcomb Steel of New England, Inc.
FLORIDA
Jacksonville
Florida Metals, Inc.
Miami
Florida Metals, Inc.
Tampa
†Florida Metals, Inc.
GEORGIA
Atlanta
†J. M. Tull Metal & Supply Co., Inc.
IDAHO
Boise
Pacific Metal Co.
ILLINOIS
Chicago
†Central Steel & Wire Company
Corey Steel Co.
†Steel Sales Corp.
INDIANA
Indianapolis
Steel Sales Co. of Indiana, Inc.
KANSAS
Wichita
Marsh Steel Corp.
Metal Goods Corp.
KENTUCKY
Louisville
Williams & Co., Inc.
LOUISIANA
New Orleans
Metal Goods Corp.
MARYLAND
Baltimore
Whitehead Metal Products Co., Inc.
MASSACHUSETTS
Cambridge
Whitehead Metal Products Co., Inc.
MICHIGAN
Detroit
Central Steel & Wire Company
Steel Sales Co. of Michigan
MINNESOTA
Minneapolis
Steel Sales Co. of Minnesota
MISSOURI
Kansas City, North
†Marsh Steel Corp.
Metal Goods Corp.
St. Louis
†Metal Goods Corp.
NEW HAMPSHIRE
Nashua
Edgcomb Steel of New England, Inc.
NEW JERSEY
Harrison
Whitehead Metal Products Co., Inc.
Hillside
Miller Steel Co.
Kenilworth
Kenilworth Steel Co.
NEW YORK
Albany
†Eastern Brace-Mueller-Huntley, Inc.
Buffalo
Brace-Mueller-Huntley, Inc.
Whitehead Metal Products Co., Inc.
New York
(L. I. City) Adam Metal Supply Co., Inc.
Eastern Brass & Copper Co.
Manhattan Brass & Copper Co.
Straus Aluminum Company, Inc.
†Whitehead Metal Products Co., Inc.
Rochester
Brace-Mueller-Huntley, Inc.
Syracuse
†Brace-Mueller-Huntley, Inc.
Whitehead Metal Products Co., Inc.
NORTH CAROLINA
Charlotte
Edgcomb Steel Co.
OHIO
Cincinnati
Central Steel & Wire Co.
Williams & Co., Inc.
Cleveland
†The Hamilton Steel Warehouse
Jones & Laughlin Steel Corp.
Williams & Co., Inc.
Columbus
Williams & Co., Inc.
Toledo
Williams & Co., Inc.
OKLAHOMA
Tulsa
Metal Goods Corp.
OREGON
Portland
†Pacific Metal Co.
PENNSYLVANIA
Philadelphia
†Edgcomb Steel Co.
Whitehead Metal Products Co., Inc.
Pittsburgh
†Williams & Co., Inc.
York
Edgcomb Steel Co.
TENNESSEE
Memphis
Metal Goods Corp.
TEXAS
Dallas
Metal Goods Corp.
Houston
Metal Goods Corp.
UTAH
Salt Lake City
Pacific Metals Company, Ltd.
WASHINGTON
Seattle
Pacific Metal Co.
WASHINGTON, D. C.
†Southern Oxygen Co.
WISCONSIN
Milwaukee
Central Steel & Wire Company
Steel Sales Co. of Wisconsin

†Home Office

Mr. Poulson is a member of the AMERICAN WELDING SOCIETY . . . is well known as a speaker at AWS meetings and at meetings of the American Society of Tool Engineers.

Hagarty Appointed by Mallory

P. R. Mallory & Co., Inc., of Indianapolis, Ind., announced recently the appointment of James Hagarty as a sales representative for the company in the Mid-West area.

James Hagarty

A member of the AMERICAN WELDING SOCIETY, Hagarty has had more than 18 years of experience in various specialized welding fields. In more recent years he has been a sales engineer specializing with welding equipment.

Before joining Mallory, Hagarty was associated with the International Harvester Co. in Chicago, Ill., the Arps Corp. of Holstein, Wis., and the Miller Electric Co. of Appleton, Wis.

Hagarty will represent Mallory from its district office at 20 N. Wacker Dr., Chicago 6, Ill.

McCauley Promoted by Ohio State

Ohio State University has announced appointment of Roy B. McCauley, Jr., as chairman of the department of welding engineering.

McCauley, an associate professor of welding engineering, joined the staff of the University in October 1950, as an instructor of welding engineering. Prior to joining the staff of Ohio State, he was assistant professor of metallurgical engineering at the Illinois Institute of Technology in Chicago. While at that institution he was head track coach, and from 1944 to 1946 served as acting department head of metallurgical engineering.

Roy B. McCauley, Jr.

The department of welding engineering at Ohio State is the only degree-granting department of its kind in the country. It was established as a separate department in 1948.

McCauley is a graduate of Cornell College in physical chemistry and received the master of science degree in physical metallurgy from Illinois Institute of Technology. He is a member of Sigma Xi, Pi Tau Sigma, Phi Lambda Upsilon, Sigma Gamma Epsilon, and Tau Beta Pi honorary fraternities. His professional society memberships include the American Institute of Mining and Metallurgical Engineers, American Society for Engineering Education, AMERICAN WELDING SOCIETY, and the American Society for Metals. He has been a director of the Columbus Section of the AMERICAN WELDING SOCIETY and is currently the vice-chairman of that group.

Huff Named by Airco

Effective Sept. 1, 1955, H. A. Huff, Jr., welding specialist, Air Reduction Sales Co., New York, was appointed regional process representative for the Magnolia (Southwest) Region, it was announced by A. C. Brown, Jr., general sales manager. Mr. Huff's headquarter will be in Houston, Tex.

H. A. Huff

With Pureco CO_2, one man efficiently welds over 100 units per hour. The Walker-Michigan Company, Jackson, Michigan (a division of the Walker Manufacturing Company of Wisconsin), prominent metal fabricators, employ this shielding gas to produce economical welds more rapidly.

Low cost inert gas shield!

For certain welding operations CO_2 is proving *an ideal inert gas shield* – economically and productively.

Pure Carbonic Company supplies CO_2 in all forms – gas, liquid, solid – for hundreds of Industrial uses. Your Pureco salesman is prepared to give you the service you need to put CO_2 to work for you *profitably*. He is at your disposal. Select the Pureco depot nearest you from the list on the opposite page.

PURECO **Pure Carbonic Company**

A Division of Air Reduction Company, Incorporated

General Offices: 60 East 42nd Street, New York 17, N. Y.

PURECO O_2

from these convenient distribution points

ALABAMA
BIRMINGHAM—Phone: 53-1626
MOBILE—Phone: Hemlock 3-2811
MONTGOMERY—Phone: 6868
ARKANSAS
LITTLE ROCK—Phone: Franklin 4-8550
CALIFORNIA
BERKELEY—Phone: Landscape 6-2155
FRESNO—Phone: 2-5222
LOS ANGELES—Phone: ADams 1-9361
SAN DIEGO—Phone: Belmont 9-6855
CONNECTICUT
NEW HAVEN—Phone: Spruce 7-4436, 7
FLORIDA
JACKSONVILLE—Phone: Evergreen 7-7425
TAMPA—Phone: 2-0304
GEORGIA
ATLANTA—Phone: Dixie 2401
ILLINOIS
CHICAGO—Phone: Wabash 2-8503
PEORIA—Phone: Peoria 7-4113
SPRINGFIELD—Phone: 3-6161
INDIANA
FORT WAYNE—Phone: Anthony 3222
INDIANAPOLIS—Phone: Melrose 2-2331
IOWA
DES MOINES—Phone: 2-0449
KANSAS
KANSAS CITY—Phone: Grand 6705
WICHITA—Phone: Amherst 2-8965
KENTUCKY
LOUISVILLE—Phone: Wabash 7274
LOUISIANA
BATON ROUGE—Phone: 4-3928
NEW ORLEANS—Phone: Cedar 7291
MARYLAND
BALTIMORE—Phone: Broadway 4402
MASSACHUSETTS
CAMBRIDGE—Phone: Kirkland 7-6044
MICHIGAN
DETROIT—Phone: Tashmoo 6-6210
MINNESOTA
AUSTIN—Phone: 2381
ST. PAUL—Phone: Prior 6431, 2, 3
MISSISSIPPI
JACKSON—Phone: 4-4838
MISSOURI
KANSAS CITY—Phone: Grand 6705
ST. LOUIS—Phone: Chestnut 1-2244
NEW JERSEY
DEEPWATER—Phone: Pennsgrove 2903
NEWARK—Phone: Bigelow 2-0400, Rector 2-4380
NEW YORK
ALBANY—Phone: 8-2719
NEW YORK—Phone: Bryant 9-1147
NIAGARA FALLS—Phone: 4-2421
NORTH CAROLINA
CHARLOTTE—Phone: Edison 3-6123
OHIO
AKRON—Phone: 5658
CINCINNATI—Phone: Mulberry 4793
CLEVELAND—Phone: Olympia 1-6520
COLUMBUS—Phone: Capital 4-9624
LIMA—Phone: Lima 4-6511
OREGON
PORTLAND—Phone: Broadway 2467
PENNSYLVANIA
ERIE—Phone: 2-3750
HARRISBURG—Phone: 4-3253
PHILADELPHIA—Phone: Walnut 2-1991, 2-6770
PITTSBURGH—Phone: Cedar 1-7780
READING—Phone: 2-3171
SCRANTON—Phone: 4-1537
TENNESSEE
KNOXVILLE—Phone: 4-5833
MEMPHIS—Phone: 5-7443
NASHVILLE—Phone: 4-8926
TEXAS
DALLAS—Phone: Riverside 6084
VIRGINIA
RICHMOND—Phone: Richmond 5-6939
WASHINGTON
SEATTLE—Phone: Elliott 8252
WEST VIRGINIA
CHARLESTON—Phone: 3-1677
HUNTINGTON—Phone: 3-7144
WISCONSIN
MILWAUKEE—Phone: Broadway 3-6914

Mr. Huff has been with Air Reduction since 1942 and has been closely associated with the welding industry for over 30 years. As an AMERICAN WELDING SOCIETY member, he has presented many technical papers and has actively participated in numerous panel discussions concerning inert-gas-arc welding, oxy-acetylene welding, brazing and other subjects.

Clarke Promoted

Sheldon V. Clarke has been appointed Manager of General Purchasing Department of Union Carbide and Carbon Corp. it was announced by Morse G. Dial, President. He succeeds Mr. H. V. Huffard who is retiring after forty years of service with the Corporation.

Mr. Clarke, a graduate of Lehigh University, first joined the Union Carbide organization in 1920. He served as construction engineer in the Construction and Design Department of Linde Air Products Co. and later held the same position in Carbide and Carbon Chemicals Co. In 1929 he left Union Carbide and joined the Bradstreet Company, becoming a Vice-President. Mr. Clarke returned to Union Carbide in 1934 as Purchasing Agent. In 1946 he was appointed Assistant Manager of Purchases.

He's alive... and you helped

People still die from tuberculosis—this year one American every twenty-seven minutes!

Yet the money which you give for Christmas Seals has helped to save thousands of lives.

Christmas Seals fight tuberculosis year-round—through education, case finding, patient rehabilitation, and research.

Make Christmas Seals a part of *your* holiday giving, today.

CHANGE OF RESIDENCE ADDRESS OR COMPANY AFFILIATION

Date .....

(Please Print)

Name .....
LAST FIRST MIDDLE

Residence
Address .....
STREET

.....
CITY ZONE STATE

Company Name
and Address .....
COMPANY NAME

.....
STREET

.....
CITY ZONE STATE

Title of position held .....

Mail should be sent to my residence ☐ company ☐ (check one)

I wish to be affiliated with the ..... AWS Section

Note: To assure that your copy of the Welding Journal is mailed to your new address, this change of address notice must be received at American Welding Society, 33 West 39th Street, New York 18, N.Y., no later than the 25th of the month previous to issue mailing.

NEWS of The Industry

Inco's Field Headquarters Relocated

Headquarters of the Central Atlantic Coast Technical Field Section of the International Nickel Co.'s Development and Research Division are now located in the Philadelphia area, in the Abington Bldg., 1150 York Rd., Abington, Pa., according to an announcement by Donald J. Reese, assistant manager of the Division. The Section headquarters formerly were located at 67 Wall St., New York City.

The territory covered by the Section embraces the New York City area, including Long Island and Poughkeepsie, New Jersey, Delaware, Maryland, Virginia, District of Columbia and Pennsylvania east of Harrisburg. The Section furnishes industry with technical information and assistance relating to nickel and alloys containing nickel.

William C. Mearns, who has been in charge of the Section since 1945, continues as its head.

Holiday Plastics Adds Subsidiary

The Thermacote Welding Products, Inc., and the Thermacote Manufacturing Co. announce that they have become a wholly owned subsidiary of Holiday Plastics, Inc., 410 E. 27th Terrace, Kansas City 8, Mo., effective July 1, 1955.

George K. Frischer is the new President of the over-all operation, with Robert Vaillancourt remaining President of Thermacote Division and Richard Vaillancourt Vice-President in Charge of Sales. C. W. Niederauer remains in his capacity as General Manager of the Thermacote Division.

RWMA Members Guests of Westinghouse

Members of the Resistance Welder Manufacturers Assn. were guests of the Motor & Control Division at a meeting held at the Westinghouse plant in Buffalo on Friday, September 23rd.

The program included a number of talks by executives of Westinghouse relative to the solution of mutual problems, and covered the latest developments in control systems. The day's activities ended with a very interesting tour of the Controls Section, and other departments of the plant.

RWMA "Seal of Quality" Plates Developed

A special metal plate has been developed by the Resistance Welder Manufacturers' Association for use by its Members on machines they produce.

This plate, indicating that the manufacturer of the welding machine is a member of RWMA, is, in effect, a "Seal of Quality."

The design of the plate appears as a part of the Association's promotional leaflet which features the activities and literature made available to Industrial and Educational fields by RWMA.

Sciaky Sales Offices Opened

In order to provide a local contact for immediate attention to calls for sales information or service, two new Sciaky Sales and Service offices have been opened—Southeastern: Sciaky Bros., Inc., 231 Healy Bldg., Atlanta 3, Ga., and Western: Sciaky Bros., Inc., 79 Bank of America Bldg., San Diego 1, Calif.

Industrial Air Products Opens Distribution Plant

Industrial Air Products Co. of Portland, Ore., has opened a new distribution branch in Kennewick, Wash., to serve the Kennewick-Pasco-Walla Walla area, according to President Gilbert Schnitzer.

Bert Morrow will manage the Kennewick plant. He has been with Industrial Air Products Co. for the past five years and has been transferred to Kennewick from the Portland office.

The new branch will carry a complete inventory of General Electric welding supplies and machines, Victor and National cutting and welding equipment, Jackson products, Stoody hard facings, Tweco products, Hewitt twin hose, Belden cable and Miller welding machines.

Liquid Carbonic Opens New Plant

On September 13th, the Liquid Carbonic Corp. opened its $1,500,000 carbon dioxide plant in Oakland, Calif. This facility is claimed to be the largest of its kind on the West Coast and reportedly comes as close to complete automation as there is in the world today.

Carbon dioxide, or CO_2, in its liquid, gaseous and solid (dry ice) forms, is produced at the new plant. The capacity is from 50 to 60 tons of CO_2 daily.

This plant approaches complete automation as nearly as any industrial facility in the country. It will require only one production man per shift to operate the entire plant, with a second man to handle dry ice for storage purposes.

The plant is practically accident-proof. An interlocking safety system of alarms and lights would automatically detect any irregularity, stop operation if necessary, and indicate where the irregularity occurs.

The Oakland plant is the largest complete manufacturing facility in the industry on the West Coast. Yet because of the nature of the process, it occupies only one half of a three-acre plot.

COMING EVENTS

A Calendar of Welding Activity

AWS National Meetings

1956 Spring Meeting:
May 8–12, Statler Hotel, Buffalo, N. Y.

1956 Fall Meeting:
October 8–12, Cleveland Hotel, Cleveland, Ohio.

NWSA Meetings

Southeastern Zone:
December 5th and 6th, The Dinkler Plaza, Atlanta, Ga.

Southwestern Zone:
December 8th and 9th, Shamrock Hotel, Houston, Tex.

Progressive now offers YOU welding equipment built to your requirements on a TRUE LEASE basis.

Get that equipment you need now! Let it pay its own way.

- **No capital tie-up.**
- **Small cash outlay.**
- **Finest welding equipment built to YOUR specifications.**
- **Advantageous tax write-off.**
- **No obsolescence problems.**
- **Lease tailored to your situation.**

A sound idea with many advantages for YOU. We will be pleased to give you full details. Write or Phone.

PROGRESSIVE *Welder Sales Company*

915 Oakland Avenue • Pontiac, Michigan

Machine Tool Design Awards

Dr. Max Kronenberg, Consulting Engineer, Cincinnati, Ohio, and Paul Maker and Edward Dix, Senior Research Engineer and Project and Design Engineer, respectively, with Bryant Chucking Grinder Co., Springfield, Vt., shared the $3000 first award in the recent $12,000 Machine Tool Design Award Program sponsored by The James F. Lincoln Arc Welding Foundation of Cleveland, Ohio. The award was made for a paper they wrote describing development work on vibration and rigidity undertaken in designing a new internal grinding machine with welded steel construction.

The paper received top honors in a national competition in which many of the major machine tool companies were represented. The program was sponsored, according to Dr. E. E. Dreese, Chairman of the Lincoln Foundation, in order to aid the further progress of machine tools. The papers, Dr. Dreese reports, definitely indicate an accelerated trend to welded design. A total of 15 awards, amounting to $12,000, was made to engineers for reports of improvements in machines made by welded design.

The new Bryant internal grinder was developed by the Bryant company to create a machine that would hold closer tolerances at higher speeds than conventional grinders, by increasing rigidity and freedom from vibration through welded construction. The production machine developed is claimed to give a saving in grinding time of 50%, a much better finish and much better control of dimensional variation. In addition, costs were reduced 43% and weight, 26%.

Leonard McDermott and Richard Fleury, Foreman and Stylist for the Brown and Sharpe Manufacturing Co., shared the $2500 second place award. They wrote a paper describing successive redesigns of a grinder base which was changed from a design in steel that simply copied a casting to a steel design which was tailored to take full advantage of the economies of welded fabrication techniques. A savings of 37% resulted.

George Kasselmann, Design Engineer with the R. K. LeBlond Machine Tool Co., received the program's third award of $2000. Fourth award of $1500 went to Alex Durand of the Falk Corp. and fifth award of $1000, to William Morgan of the Clearing Machine Corp.

Honorable mention awards of $200 for reports of similar improvements went to engineers from ten other companies.

West Coast Representative

The Sullivan-Cassimus Co., of Los Angeles and San Francisco, has recently been appointed West Coast representative for the Federal Tool Engineering Co., of Cedar Grove, N. J.

The offices of Sullivan-Cassimus, located at 110 W. Pico Blvd., Los Angeles, and at 651 Folsom St., San Francisco, Calif., are now available for any Engineering, Sales, and Service information regarding the complete line of "Tweezer Weld" small and miniature part welding equipment and services, and will also serve as the West Coast Display Headquarters for standard Federal Tool Engineering Co. equipment.

Sullivan-Cassimus, as the new West Coast representative, completes national representation of the "Tweezer Weld" line by joining other Federal Tool Engineering Co. representatives in Buffalo, Cleveland, Chicago, Philadelphia, Detroit, Indianapolis, and their home office located in Cedar Grove, N. J.

Buy Aronson
TURNING ROLLS
for Automatic Welding
or for Manual Welding

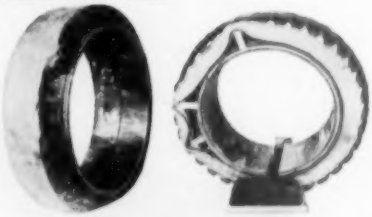
Micrometer controlled speed, ZERO to Maximum Inches Per Minute . . . Precision Cut Gears with Absolute Minimum Backlash . . . Built-In MAGNETIC BRAKING for smooth, precise stops . . . Low Voltage Control Circuit . . . Magnetic Reversing Starter and Safety Disconnect switch . . . Anti-Friction Bearings Throughout . . . Precision Steel Ways and exact diameter settings . . . Gear-boxes Packed for Life . . . All Rolls stressed for 100% Overload Protection.

Overloading or accidentally dropping the load on an Aronson Turning Roll WILL NOT crush and ruin the tire. The Overload Disc of steel placed on each side of each tire is smaller than the tire by just that amount which allows a safe deformation (flattening) of the tire which occurs at maximum load. Compression and tension Tie-Rods hold the Overload Discs firmly against the steel rim of the rubber tire, forming an effective axle as large in diameter as the O.D. of the steel tire rim. Crushing the tire is impossible regardless of the load put on an Aronson Turning Roll. Large Timken Bearings maintain perfect alignment.

Any Tank or Cylinder will be somewhat out-of-round and will not be straight, but will have a belly or bend in its average centerline axis. In the case of non-rigid cylinders, multiple rolls are used to hold a true centerline, ironing out the belly or bend. When working rigid tanks and cylinders, it is best to have one roll at each end so as to avoid the belly placing all the load on the middle roll when that belly is down, and all the load on the two end rolls when the belly is up. It is to allow for the average amount of out-of-round and belly in cylindrical workpieces that ARONSON has stressed all units for 100% overload Protection. Momentary overloads as high as 100% will not breakdown an Aronson Roll.

AVOID DAMAGE LIKE THIS

UNDERCUTTING CAUSED BY OVERLOADS
Continuous overloads on this tire caused the rubber to bulge out over the steel band. This, in turn, set up a shearing or cutting action in the tread. Tire is ripped around the bond on both sides and is about ready to fall off.



Courtesy of the Rubber Manufacturers Assoc., Inc.

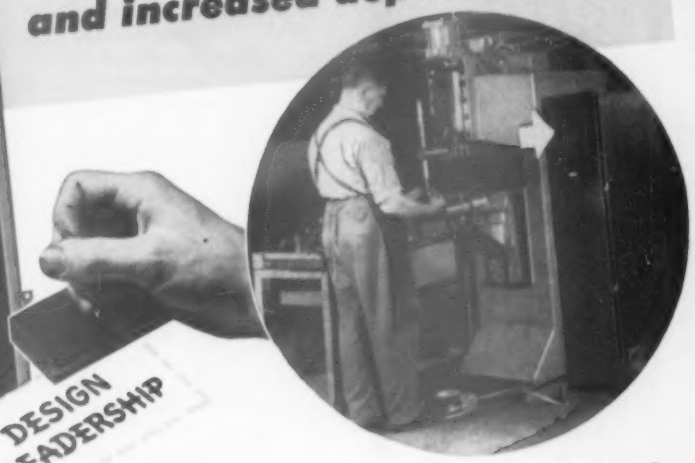
Send for Specification Brochure

Aronson MACHINE CO. WORK WORK ARCADE, N. Y.

Simplified Precision Welder Control

for easier maintenance and increased dependability

Class 8993 NEMA Type S2H **Synchronous-Precision Controller** available with 600 or 1200 frame contactor. Can be arranged either for side of machine or wall mounting.



DESIGN LEADERSHIP

APPLICATION: *for welding stainless steel, nonferrous metals, and other critical spot welding jobs requiring electronic synchronous-precision control. (Available with current wave shape control auxiliaries for aluminum or alloy metals.)*

DESIGN LEADERSHIP features

Easier Maintenance . . . greatly simplified circuits require fewer tubes and only one operating relay (for the air valve).

Increased Dependability . . . all components designed specifically for industrial welder service. Tube circuits are fail-safe and initiating contacts are in isolated 24 volt circuit which supplies power to the valve relay.

Consistent Accuracy . . . regulated DC voltage on tube control grids compensates for supply fluctuation or tube variations . . . assures timing accuracy.

Greater Accessibility . . . timer, heat control and firing panels designed for easy inspection and maintenance, with quick fasteners and plug connectors.

Write **for BULLETIN 8993**
or consult your nearby Square D Field Engineer

SQUARE D COMPANY

there is a Dockson OUTFIT "complete" at one low price to WELD or CUT

FOR EXAMPLE—The Dockson No. 145 Outfit illustrated above is for light and medium welding and cutting jobs up to and including 5" steel. At one low price you get—

1—No. 44-C Hi-Speed Welding Torch ● 1—Ea. Nos. 2, 4, 6, 8 and 10 "T" Style Tips ● 1—C-4 Hi-Speed Cutting Attachment ● 1—C-2 Cutting Tip ● 1—No. 134-R Oxygen Regulator, 200 lb. and 3000 lb. gauges ● 1—No. 134-AD Acetylene Regulator, 50 lb. and 500 lb. gauges ● 1—Commercial to P.O.L. Adapter ● 1—12½ ft. length ¼" Siamese Hose ● 4—Hose Connections ● 1—Outfit Wrench ● 1—Round File Gas Lighter ● 1—Pr. Series 66-10-G Welding Goggles.

YOUR DOCKSON DISTRIBUTOR—is a carefully selected specialist who carries a complete line of Dockson Products in stock to give you fast service and personal attention. We back our distributors 100%.

WRITE FOR YOUR DISTRIBUTOR'S NAME AND OUR COMPLETE CATALOG OF WELDING AND CUTTING EQUIPMENT. BUILT FOR BETTER SERVICE.

Dockson CORPORATION
3359 WABASH • DETROIT 8, MICH.

Farm Welding Contest

On Aug. 17, 1955, the Phoenix Welding Supply Co., 112 S. 6th St., and the manufacturers they represent—the Dye Oxygen Co., the Stoody Co. and the Smith Welding Supply Co.—gave over five hundred dollars worth of prizes in their annual Farm Welding Contest.

This is a contest designated to promote better understanding of farm welding and machine designing and repair so that the students may be better able to take their place in farm and industry.

The contest was opened to all students in the state of Arizona enrolled in a vocational agricultural class. The student had to build this project using less than 50% new material and so certified by his agricultural teacher. The judges were prominent men from Phoenix: J. A. Rau, chief engineer of the Allison Steel Manufacturing Co., and Charles Fogwell of the Fogwell Machine Co., both members and executives of the Arizona chapter of the AMERICAN WELDING SOCIETY, and Douglas Todd, a member of the State Farm Bureau and a successful farmer himself.

The first prize, valued at $204, won by Greg McCleery, a member of the Coolidge F. F. A. chapter, was a new Smith Midline welding and cutting outfit plus a set of oxygen and acetylene tanks donated by the Smith Welding Co. and the Dye Oxygen Co., respectively. The second prize went to John Hightower, of the Benson F. F. A. who received a Hobart 180-amp, a-c Welder complete with hood and cable, valued at $199.50 which was donated by Phoenix Welding Supply Co. and Dye Oxygen Co. The third prize went to Joe Anderson of the F. F. A. of Chandler who won a Stoody jig and 20 lb of assorted hard-facing rod valued at $100.

The Phoenix Welding Supply Co. has made this contest an annual affair for the students in the State of Arizona.

Alloy Rods New Research Laboratory

E. J. Brady, president of the York, Pa., electrode manufacturing concern, announced the formal opening of the company's new research and development center. The new structure, devoted exclusively to product research and quality control, is located adjacent to the general offices and plant at York.

Facilities include chemical, physical testing and welding laboratories, as well as a complete machine shop and experimental mixing and extrusion department. All departments are equipped with the most modern equipment available for the development and improvement of electrodes and weld metal. The entire building and its facilities are designed for maximum efficiency, placing all related departments and equipment in close proximity to one another.

In the arc welding of alloy steels, chemical analyses are extremely important, not only in product research but in quality control of the manufactured product. The chemical laboratory, therefore, plays an important role in both the development and quality control of alloy electrodes.

The modern mixing and extrusion department is laid out so that it is almost an exact replica, in miniature, of the production facilities in the manufacturing plant. Thus, in the design and development of new electrodes, all pos-

(*Left to right*) **Gil Dye, Jr., Phoenix Welding Supply Co., Greg McCleery, Coolidge, first place winner in Welding Contest, and John Hightower, Benson, second place winner in welding contest**

gives complete, automatic arc control

IN ANY WELDING POSITION:

...overhead
...vertical
...downhand

an exclusive feature

of the new VICKERS® *Controlarc*

magnetic amplifier-rectifier *DC Welder*

in 200, 300, 400 Ampere Models

- Individual, Stepless, Full Range Control of Voltage and Current
- Full Range Remote Control Available
- Easy, Clean Arc Strikes
- Hot Starts, Immediate Penetration
- Fast Arc Recovery
- No Current Drop-Off During Pass
- Uniform Fusion, Steady Rate of Metal Deposit
- Adaptable to Inert-Arc Applications

WRITE TODAY
for new bulletin

Some territories open for qualified dealers. Write for details

VICKERS ELECTRIC DIVISION

VICKERS Inc. a unit of Sperry Rand Corporation

1853 LOCUST STREET • SAINT LOUIS 3, MISSOURI

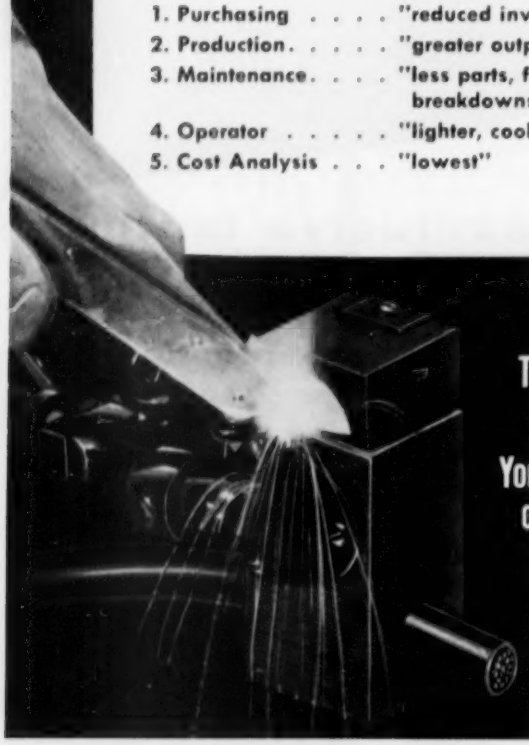
HAS YOUR PLANT TRIED

CADDY?

CADDY Arc Welding Accessories are all designed to utilize the finest of all electrical connections—CADWELD. From welding machine to electrode, the CADWELD connection has revolutionized the arc welding circuit. Today after five years of on the job analysis, companies all over the United States are standardizing on CADDY Arc Welding Accessories and CADWELD cable splicing.

The reason for the acceptance of the complete CADDY Arc Welding Circuit is that it proves itself to:

1. Purchasing . . . . "reduced inventory"
2. Production. . . . . "greater output"
3. Maintenance. . . . "less parts, fewer breakdowns"
4. Operator . . . . . "lighter, cooler"
5. Cost Analysis . . . "lowest"



Try CADDY TODAY— You'll standardize on CADDY tomorrow

CADDY®

Arc Welding Accessory Div.

Erico Products, Inc.

2070 E. 61st Place • Cleveland 3, Ohio

IN CANADA: ERICO INCORPORATED, 3571 Dundas St., West, Toronto 9, Ontario

sible production difficulties become apparent and are compensated for, so that the new product can easily be fitted into production schedules.

The physical aspects of developing, testing, and controlling the quality of electrodes takes place in the welding and physical testing laboratories. All types of welding equipment, both manual and automatic, are available for weldability and physical property tests. All welding machines are equipped with the most modern recording and testing instruments to register every factor important to arc characteristics, weldability and the improvement of mechanical properties. The machine shop then prepares these specimens for physical properties tests in the physical testing laboratory.

Distributor Appointment

The Charles S. Freeman Co. of Buffalo, N. Y., has been appointed to represent the Unique Turntable & Equipment Corp. of Brooklyn, N. Y., in the greater portion of New York State and Northwestern section of Pennsylvania.

Superweld Subsidiary

Western Carbide Corp. has been formed as a subsidiary of Superweld Corp., North Hollywood, Calif., to manufacture and market proprietary products. The new corporation is making a hard-facing paste and several hard-facing bulk products.

ASTM Holds 58th Annual Meeting

With a near-record registered attendance of 2537, exceeded only by the 50th Anniversary Meeting in New York with 2602 in attendance in 1952, the American Society for Testing Materials brought to a close its 58th Annual Meeting at Atlantic City, N. J., on July 1. At the week-long meeting with some committees getting together as early as Saturday, June 24, the Society held 32 Technical Sessions and approximately 700 technical committee meetings. Sixty-six of the Society's technical committees presented reports. Sixty-seven new specifications and methods of test were approved as tentative, and revisions in 351 existing tentatives and standards were acted upon. A total of 119 specifications and methods of test previously designated as tentative were approved for reference to Society letter ballot for adoption as standard.

Claire H. Fellows, Director, Engineering Laboratory and Research Dept., Detroit Edison Co., Detroit, was elected president of the Society for a one-year term.

ACCO products

3 Big Reasons for Buying PAGE Automatic Welding Wire

1. PACKAGED TO FIT YOUR PARTICULAR REQUIREMENTS
2. A WIDE RANGE OF ANALYSES TO FIT A PARTICULAR JOB
3. GREATEST CONVENIENCE—YOU CAN BUY FROM LOCAL STOCKS

PAGE packages its great line of welding wires in a variety of ways for utmost protection and convenience in handling, stocking and using.

Some of these packaging methods are shown at the left...There are lightweight, durable Leverpaks which give protection against coil distortion or wire corrosion. Easily opened and resealed, they roll easily and stack perfectly. They take a minimum of floor space.

There are single and pallet-mounted (1,000 lb., 2,000 lb., 3,000 lb.) coils, each wrapped in waterproofed paper and held secure by steel strapping; thread-wound, 25-pound reels to fit popular machines; also, coils in individual cardboard cartons, available singly or palletized for handling by fork-lift truck.

PAGE offers exactly the Right Analysis —26 in all—for every Welding Job . . .

No matter how "special" or "different" your welding-wire requirements may be, they can be met by one of the *26 different analyses* in the PAGE line.

These "cover the waterfront" of applications: heavy automatic submerged arc...light manual submerged arc...inert gas manual and automatic, tungsten or metal arc.

Carbon Steel • Any carbon from Armco (.025 max.) to high carbon (.90—1.10)

Low Alloys • All the most popular welding grades

Stainless • All standard AISI grades. Other types on request

The Right Electrodes, Rods, Spray Wire

Your welding job deserves the *right* electrodes and the *right* rods—and you can get them from the wide range offered by PAGE!

Gas Welding Rods • Armco, mild steel, low alloy, 3½% nickel, carbon or stainless steel, manganese or naval bronze

Bare Electrodes • Any carbon from Armco to high (.90—1.10) carbon

Metal Spray Wire • Any carbon from Armco to 1.00 carbon; also 3½% nickel, manganese or naval bronze, and stainless steel

Convenient Service from Local Stocks

Wherever you live, your nearby PAGE Distributor can fill your needs quickly and easily. This handy service saves time for you, and lets you keep your inventory investment at a minimum. Your PAGE Distributor thus makes double savings for you—a saving in time and a saving in dollars.

ACCO

Page Steel and Wire Division
AMERICAN CHAIN & CABLE

Monessen, Pa., Atlanta, Chicago, Denver, Detroit, Houston, Los Angeles, New York, Philadelphia, Portland, Ore., San Francisco, Bridgeport, Conn.

Better Value

NEW LITERATURE

Temperatures Measured

The Tempil® Corp. of 132 W. 22nd St., New York 11, N. Y., less than a year ago published an 8-page booklet on *How Temperatures Are Measured*. Three printings have almost been exhausted. Contact company at above address for copy.

Titanium Booklet

An illustrated booklet giving up-to-date data on the properties of titanium and discussing methods of fabricating the lightweight metal has been issued by Du Pont's Pigments Department, Wilmington, Del.

The booklet includes tables giving the mechanical properties of both alloyed and unalloyed grades of the metal, and comparative properties of titanium and other pure metals.

It discusses methods of forging, annealing, rolling, and descaling and pickling titanium sponge in primary fabrication; and sheet forming, machining, grinding, sawing and joining of titanium in secondary fabrication.

The expanding range of commercial applications of titanium is indicated in photographs showing uses for titanium in the chemical industry, in commercial aircraft and in the food-processing industry.

Technical Services Offered

Technical data and information on the newest electric resistance welding research and application to problems of industrial fabrication will be sent free of charge to individuals or concerns requesting them on professional letterheads, it has been announced by the Sciaky Research Center, a division of Sciaky Bros., Chicago.

The research and development work will cover a variety of items from aircraft structural welding to light industrial applications. Metals used include various alloys, nickel, Inconel, titanium, zirconium, stainless steels and metals in the nimonics series.

The program at the Research Center includes development of new resistance welding applications, joint patterns, structural qualities, economics of resistance welding design and the making of these data available to industry.

Requests for these data should be addressed to Technical Editor, Sciaky Research Center, 2311 Purdue Ave., Los Angeles 64, Calif.

Textbook of Structural Shop Drafting

The American Institute of Steel Construction has published the third and last volume of its *Textbook of Structural Shop Drafting*.

Volume 3 covers complicated details of trusses and girders, both riveted and welded. It is suitable for use in advanced training in structural shop drafting, as a supplementary reference for courses in structural design, and in design office practice.

The book is similar in style and appearance to the earlier volumes and contains 218 pages.

It is for sale at $3.00 per copy, shipping charges prepaid in the U. S. A. and Canada. Orders are being accepted at the Institute offices, 101 Park Ave., New York 17, N. Y.

Help Wanted

Several months ago, the Army Ordnance Corps initiated the preparation of a comprehensive Ordnance Engineering Design Handbook to summarize fundamental principles and basic design data. The handbook is being written to provide needed information to army ordnance and arsenal personnel and to the engineering staffs of contractors having ordnance design responsibilities. It is planned that the handbook will consist of approximately 180 sections of about 100 pages each. Completion of the first edition of the handbook is expected to require about five years. The format is being worked out so as to facilitate revision of individual sections as may be required by future developments.

Ordnance engineering cuts across many fields of science and technology, and information for design work is drawn from many diverse fields of knowledge Those whose subject field is of interest in ordnance work, and who have either formal or informal collections of terminologies, glossaries, specialized dictionaries, or even references to them are asked to contact Allen Kent, Associate Director, Center for Documentation and Communication Research, School of Library Science, Western Reserve University, Cleveland 6, Ohio.

Aluminum Solders

Two new solders, applicable in joining aluminum where 18,000 or 20,000 psi shear strength is adequate, are described in a folder published by All-State Welding Alloys Co., Inc., 249–55 Ferris Ave., White Plains, N. Y.

Single copies of the folder, or a sufficient number to supply individual copies for welder crews are free for the asking. They may be had from the company or any All-State distributor.

Finishing of Stampings

A new bulletin on the finishing of stamped metal parts by means of the airless abrasive blasting process has just been published by Wheelabrator Corp., 1332 S. Byrkit St., Mishawaka, Ind.

This bulletin contains four case histories of various companies, giving performance data and showing photographs of the equipment they use for this work. The blast cleaning of stampings is done for any of several reasons, including the preparation of surfaces for welding and brazing.

Copies of this bulletin may be obtained free from Wheelabrator Corp. Write for Bulletin No. 117-D.

Resistance Welding

Sciaky Bros., Inc., 4915 W. 67th St., Chicago, Ill., introduces Vol. 4, No. 4, *Resistance Welding at Work*, covering the case history of resistance welding the U. S. Air Force Northrop F-89D. Named the Scorpion, the F-89D is considered to have more spot and seam welding used in its fabrication than any other aircraft in its class.

For a complete description on resistance welding the F-89D Scorpion, plus "on-the-spot" photographs, write direct to Dept. L-3 at the Chicago address for your free copies of Vol. 4, No. 4.

Brazing Fixture

A new mounting fixture for brazing and soldering work is described in Technion Engineering Bulletin No. 101, just issued by Technion Design & Manufacturing Co., 262 Mott St., New York 12, N. Y. The bulletin is available free of charge.

The new fixture, called Roto-Jig, is a universal brazing or soldering work

center. It can be mounted in any standard bench vise in about thirty seconds, converting the work bench into an efficient brazing-soldering work station. Mounted on a solid steel shaft, the Roto-Jig turns through 360 deg, permitting the operator to remain stationary while the work rotates—with resulting savings in cycle time.

Press Welder

The Kirkhof Manufacturing Corp., 2450 Buchanan Ave., S. W., Grand Rapids, Mich., announce the availability of a new 8-page Press Welder folder. Copies may be obtained by writing to the above address.

Ferrous Metallurgy Chart

A revised edition of the Tempil® *Basic Guide to Ferrous Metallurgy*—in an 8½ x 11-in. black-and-white version—is now available. This chart provides a handy reference source for the engineer, metallurgist and skilled worker, and has proved to be an excellent teaching aid in fundamental courses on metallurgy.

The principal characteristics of steels (with carbon content ranging to 0.9%) are represented across the temperature range to 2900 F. The important working zones, including preheating for welding, stress relieving, normalizing, annealing and forging are shown. At the right of the chart 24 common metallurgical terms are defined and explained. A diagram symbolizing the change in grain size with temperature appears at left.

Copies of the chart are available without charge by writing to Tempil® Corp., 132 W. 22nd St., New York 1, N. Y.

REVIEWS
OF NEW BOOKS

Manufacturing Processes

Modern Manufacturing Processes, by Prof. Joe L. Morris, Georgia Institute of Technology. Price $9.35. 533 pages. Published by Prentice-Hall, Inc., 70 Fifth Avenue, New York 11, N. Y.

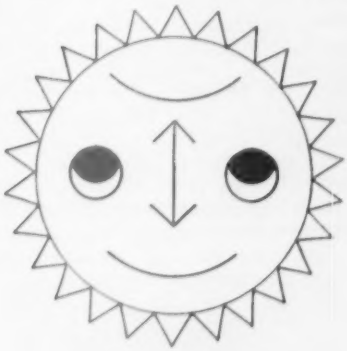
This book covers the processing on the working of commercial metals and plastics. Each process or method is described and evaluated to give the reader a clear idea of its relative importance in modern industry.

One entire chapter is devoted to welding processes and applications. The others deal with the production of metallic raw materials, casting methods, rolling, forging, machining, and measuring, testing and inspection.

Text is aimed at industrialist, engineer or student with its comprehensive treatment of the newest manufacturing processes.

Safety Plus Super Control!
NEW
Meco
DUBBL STAGE
REGULATOR
• Stainless steel diaphragm on both stages. Won't set . . lasts indefinitely. Prevents crimping, distortion.
• Bronze construction—extra safe, longer lasting!
• Pin-point pressure regulation!
• Safe-T-Chek Valve prevents seat damage!
• Designed for quick, on-the-spot repairs! Seats easy to change.
• Versatile! Adaptable for use on oxygen, acetylene, hydrogen, nitrogen, argon and helium.
Distributors! Some territories available. Write!
Meco
3403 PINE BLVD • ST. LOUIS 3, MO.

The tragic fact, our doctors tell us, is that every third cancer death is a needless death... *twice* as many could be saved.



LET'S LOOK AT THE BRIGHTER SIDE

Many thousands of Americans are cured of cancer every year. More and more people are going to their doctors *in time*...To learn how to head off cancer, call the American Cancer Society or write to "Cancer" in care of your local Post Office.

American Cancer Society

NEW PRODUCTS

Deoxidizing Process

A new process, used in preparing aluminum surfaces for welding, has been announced by the Northwest Chemical Co. of 9310 Roselawn, Detroit, Mich., manufacturers of specialized chemical cleaners.

According to the manufacturer, the new "Alkalume" process thoroughly removes all soils and oxides without harming metal, thereby reducing surface resistance to a value of 0 to 10 microhms. In addition, a resistance of 10 to 20 microhms will persist for many days without reoxidation.

In addition to eliminating mechanical cleaning operations such as the use of rotary wire brushes, the Northwest method reportedly assures more perfectly formed welds, free from cracks at a worth-while saving in time and cost.

A-C, D-C Welder

An all-new, all-purpose single-phase a-c, d-c welder, available from the Westinghouse Electric Corp., for light fabrication welding affords a continuous current range, full overload protection and a high degree of portability. Fan-cooled and designed for operation from a 230-v, single-phase supply, the welder provides a-c welding currents of 25 to 250 amp of d-c-welding currents ranging from 20 to 200 amp. Primary ampere rating is 47 amp for both d-c and a-c operation.

For more information on the new RMC-4J single phase a-c, d-c welder, write Westinghouse Electric Corp., P. O. Box 2099, Pittsburgh 30, Pa.

Torch Tip Cleaners

A newly designed set of spiral tip cleaners with a double piloted cleaning action has been put on the market by Universal of Fort Lauderdale, Fla.

The smooth, double-spiral ridges provide for adequate chip clearance which allows the dirt and carbon particles to be removed from the gas and oxygen orifices without enlarging these ports.

The cleaners are made of stainless steel and the cleaning ridges are held to exact tolerances to insure uniform fit.

Full information can be had by writing to Universal Cutting and Welding Equipment Manufacturing Co., 2850 Ravenswood Rd., Fort Lauderdale, Fla.

Engine-Driven Welders

The Air Reduction Sales Co. announces the availability of two new engine-driven a-c arc welders known as models GEA200 and GEA200L. The new machines are designed for field production and maintenance welding applications where the work calls for light, rugged and dependable units. Outstanding results have been obtained in pipe heating applications—ice thawing and evacuating heavy viscous fluids.

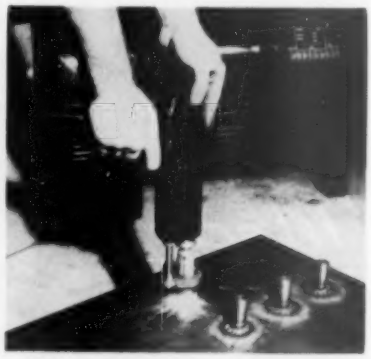
According to the manufacturer, they are well suited for all welding applications where a-c or a-c, d-c electrodes of $^1/_{16}$ to $^5/_{16}$ in. diam are required. Rated welding current is 200 amp, 100 cycle, single phase with a 100% duty cycle. Welding current range is 15 to 200 amp. Open circuit voltage is 85 v. The welding arc is exceptionally stable due to the high frequency of the welding current.

In addition to welding power, both models provide 1-kw, 110-v d-c auxiliary power. Model GEA200L also can be used to supply 4.5-kw, 110–220 v, 60-cycle, single-phase a-c, d-c power, identical to that supplied by normal power service lines.

For more information about the models GEA200 and 200L, write Air Reduction Sales Co., a Division of Air Reduction Co., Inc., 60 E. 42nd St., New York 17, N. Y.

Stud Welding Gun

Stud welding applications in construction and industry are widened by a new type gun that welds steel studs up to $1^1/_4$ in. in diameter in the fields. The gun's pistol-grip stock is less bulky than most because it is molded of glass-filled Bakelite phenolic resins, compounded



by Fiberite, which have high heat resistance and good electrical properties. Studs 1 in. in diameter are welded in a split second with this gun. It will also weld studs up to a yard long, to hold concrete forms in tunnel construction, for example. By raising the maximum diameter of studs which can be welded in the field from $^3/_4$ to $1^1/_4$ in., the new gun permits handling of larger forging billets with stud-welded handles, and provides welded fastenings for heavier industrial equipment and machinery components.

Additional information may be had by writing to Nelson Stud Welding Division of Gregory Industries, Inc., Toledo Ave. at 28th St., Lorain, Ohio.

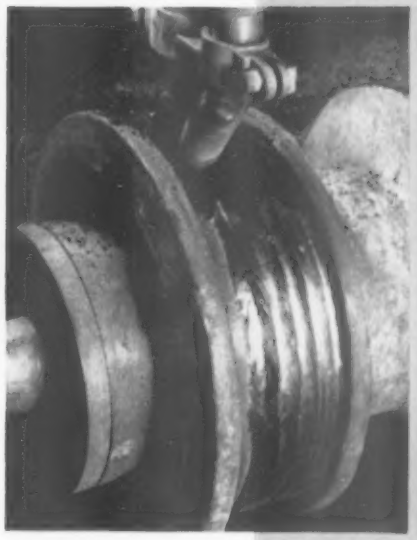
Hard-Facing Paste

The availability of hard-facing pastes which can be applied without special skill to impart a deposit of high hardness and good abrasion resistance is announced by Western Carbide Corp., subsidiary of Superweld Corp., North Hollywood, Calif.

NEW...

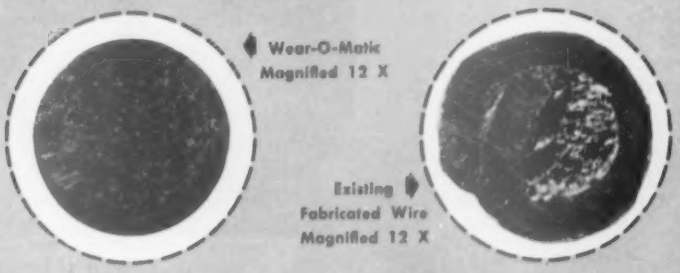
Wear O Matic

Precision drawn fabricated wire for Automatic and Semi-Automatic Hard-Facing Applications



COMPARE

this major development in fabricated wire with existing wire . . .



These cross sectional views of fabricated wire were made under identical conditions. Notice the compactness and perfect roundness of Wear-O-Matic precision drawn wire as compared to existing fabricated wire. This dense, controlled diameter wire provides the smooth feeding and excellent arc characteristics of solid welding wire and insures a weld deposit that is uniform in soundness, chemistry and hardness.

Wear-O-Matic OFFERS THESE EXCLUSIVE FEATURES

1. Smooth, trouble-free feed with any automatic head—without special feed rolls or contact tubes.
2. Precision drawn for perfect roundness to insure continuous, smooth feeding.
3. Uniform compactness for uniform chemistry and hardness.
4. Electroplated with copper to prevent surface rust and insure positive electrical contact.

Make your own comparison . . .

Write for free sample specimen of new Wear-O-Matic wire—the only fabricated wire that's as easy to use as solid wire. Compare and prove to yourself why Wear-O-Matic is the wire you want now! Just write:

DRAWALLOY CORPORATION
Lincoln Highway at Alloy Street
York 13, Pennsylvania

Drawalloy

CORPORATION

YORK, PENNSYLVANIA

Hard facing paste

According to the manufacturer, Hi-C 60 "Ruf-Nek" paste introduces an entirely new concept of hard facing. Available in tubes or jars, the new paste can be used on any metal whose melting point is higher than that of the paste (1850° F). Using gas flame, it can be applied to metal of less than 1/4 in. thickness. With proper induction heating, any thickness of metal can be hard faced. The paste is expected to be of great value in manufacture and maintenance of farm tools, earth-moving equipment and general industrial use. Numerous potential applications also exist in automotive, electronic and other industries.

For additional information, write to R. E. Jones, Superweld Corp., 6840 Vineland Ave., North Hollywood, Calif.

Constant Arc Voltage Welder

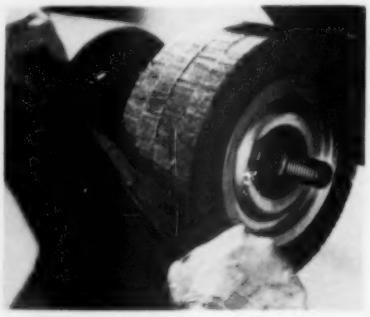
The new Airco 800-amp, TCV Rectifier arc welder is designed expressly for inert-gas-shielded consumable-electrode welding. This machine features constant arc voltage for all automatic machine welding applications employing constant speed wire feed.

With this machine the arc voltage may be preset over a wide range, from 15 to 44 arc volts. The voltage may also be preset to provide a higher initial voltage for ease in establishing the arc. Once the arc is established the voltage automatically adjusts to the preset value. This arc voltage then remains constant regardless of load conditions or changes in input line voltage.

For more information, write Air Reduction Sales Co., 60 E. 42nd St., New York 17, N. Y.

Grinding Wheels

Merit Products, Culver City, Calif., announce that they now have in production two large-diameter wheels—10 and 12 in. diameters in 1- or 2-in. widths. The larger wheels are designed for heavy-duty light grinding, burr shagging, and polishing of flat or contoured surfaces. They are very light for their size, and may be used on light equipment or in automatic setups.



Grind-O-Flex is a recent development. It consists of hundreds of "leaves" of aluminum oxide abrasive cloth sealed together at the hub, allowing complete flexibility.

For additional information write to Merit Products, Inc., 4623 Irving Place, Culver City, Calif.

Automatic Welders

The Lincoln Electric Co., of Cleveland, Ohio, announces the availability of a completely new line of equipment for submerged arc welding. The new line includes three new welding heads, new controls and adjustments, new accessories and two new power sources.

The new welding heads, LAF-3, LAF-4, LAF-5, offer to users a choice of heads for either a-c or d-c current, field or shop welding, and constant potential or variable voltage power source. According to the manufacturer, new operation controls permit a choice of instantaneous starting, either hot for intermittent welding or cold for precision starting; a choice of variable inching speeds, either slow or fast, away from or to the work; a choice of carriage operation to give stand-still starts, flying starts or manual control.

WE CAN SUPPLY YOU WITH

WELDTAN LEATHER WORK GLOVES

They're tough, comfortable and long lasting

Your order will have prompt attention

Manufacturers and distributors of a complete line of safety clothing and equipment.

Write Dept. W for information regarding your needs.

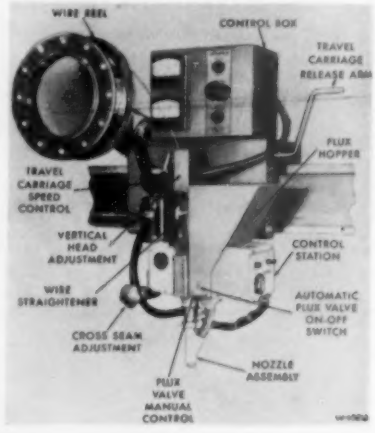
V. E. KENNEDY—INGALLS CO.

3735 NORTH 35TH STREET
MILWAUKEE 16, WISCONSIN

In addition to heads, mounting equipment is available to give either a stationary mounting, mounting on a self-propelled travel carriage or on a self-propelled tractor. The heads can be adapted for Twinarc or tandem arc welding or for an oscillating attachment, the Spreadarc.

A new Lincolnweld power source has been added to the line in the Lincolnweld AC-750, which gives 750 amp continuous duty a-c power.

Another new power source is the Lincolnweld DC-750, which is a motor generator machine specifically designed for automatic welding. It is rated at 750 amp, continuous duty at 40 v.



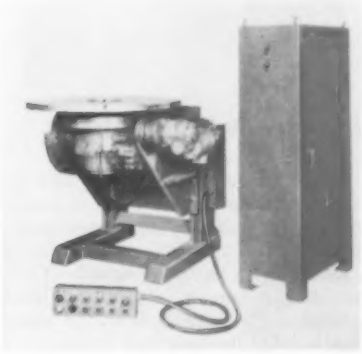
Other power sources available are Lincoln's standard 600-amp, variable-voltage d-c motor generator and a 600-amp, d-c engine-driven welder for field operation.

Lincoln's line of automatic equipment also includes electrodes for welding low-carbon steel, alloy steels, stainless steel and for hard facing. Agglomerated fluxes are available for welding these steels, as well as for welding most alloy steels with mild steel electrodes. Fluxes are also made for hard facing with a mild steel electrode.

Additional information may be had by writing directly to the company.

Welding Positioner

Sciaky Bros., Inc., 4915 W. 67th St., Chicago, Ill., announce the new design of the WP-1—Welding Positioner—used by one of the largest Jet Aircraft Engine Plants for very precise gas-tungsten-arc welding to Government specifications.



The WP-1 welding positioner is a device used in the automatic welding of a cylindrical or circular piecepart.

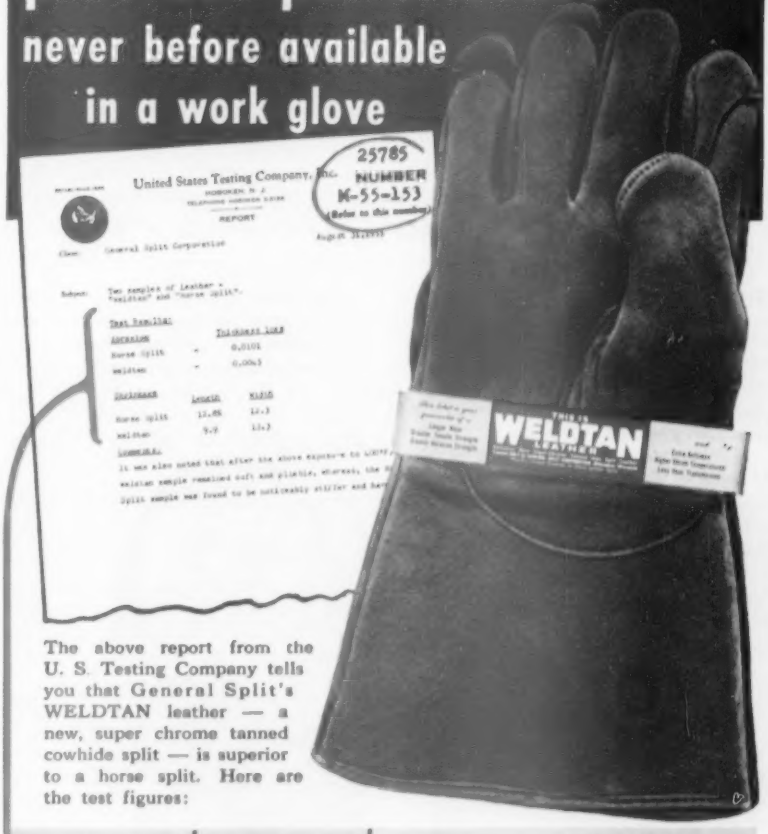
It provides the mechanical support, and the rotation of the piecepart about its axis, in front of the welding head. The rotation drive, therefore, provides the speed of travel of the arc.

According to the manufacturer, the characteristics of the welding positioner correspond to those of a very elaborate high performance speed servo mechanisms for Military applications. However, the WP-1 is a relatively inexpensive, simple, rugged device that is able to withstand the abuse of constant, production use.

This machine is a rigid weldment supporting a hollow center table of 9 in. ID and 40 in. OD. The welding positioner, with feedback control, 2500 lb capacity and of precision construction is capable of 360 deg rotation and 135 deg table tilt.

For more information of a specific application concerning this welding positioner, write to Dept. M-4 at the Chicago address.

WELDTAN* Leather provides performance never before available in a work glove



The above report from the U. S. Testing Company tells you that General Split's WELDTAN leather — a new, super chrome tanned cowhide split — is superior to a horse split. Here are the test figures:

	Horse Split	WELDTAN
ABRASION TEST Thickness Loss	0.0101—average	0.0045—average (2½ times less abrasion loss for Weldtan)
TEMPERATURE TEST Shrinkage Loss	12.8%	9.9%—(22.6% less shrinkage for Weldtan)

COMMENTS: It was also noted that after the above exposure to 400° F, the Weldtan sample remained soft and pliable, whereas, the Horse Split sample was found to be noticeably stiffer and harder.

These performance extras mean not only dollar savings and less frequent glove replacement, but increased comfort and softness mean they'll be better liked by your men. So, specify WELDTAN on your next order to your sources of supply. And for your protection against imitators in appearance — for many work gloves are now colored green — the identifying green and white band, illustrated here, is attached to every pair of genuine WELDTAN gloves.

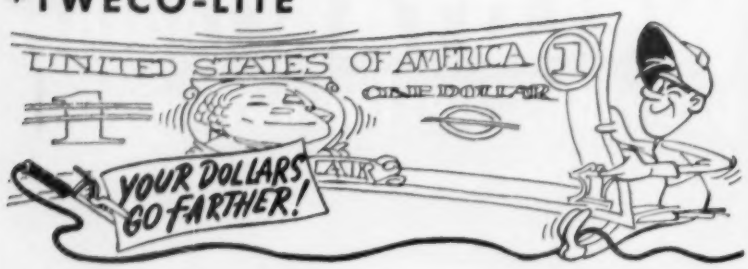
*WELDTAN leather is tanned only by

GENERAL SPLIT CORPORATION — FIVE STAR QUALITY

World's largest producer of glove leather splits

730 West Virginia Street Milwaukee, Wisconsin

*TWECO-LITE



Send for FREE CATALOG

*TWECO-LITE, the new flexible ALUMINUM welding cable that weighs half as much, costs less and lasts longer.

a product of TWECO PRODUCTS CO. Wichita 1, Kansas

Utility Welder

A new, easy to use, utility welder, especially designed for small shops, farms, garages and schools, has been placed on the market by Marquette Manufacturing Co., Minneapolis, Minn.

Marquette Model "31," an a-c 230–115 v Arc Welder, is shipped complete and ready to operate. It is equipped with an 8-ft flexible power cable in addition to a ground clamp and cable, electrode holder and cable, hand shield with lens, an assortment of welding electrodes and a complete instruction book.

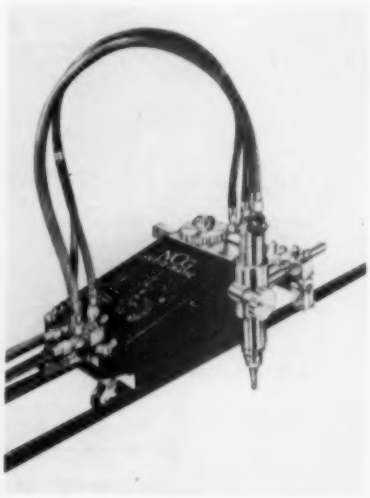
It provides six heat ranges, with a

100-amp maximum output, and welds with electrodes up to $^1/_8$ in. with ease. This portable welder, 18 in. high, 10 in. wide and $12^1/_4$ in. deep, weighs only 85 lb.

For complete details, write directly to company.

Portable Cutting Machine

Improved portability and greater cutting accuracy are claimed for a new version of the NCG Cut-O-Matic portable flame-cutting machine. According to National Cylinder Gas Co., the new model No. 7 weighs under 30 lb, including torch—20 lb less than previous models. The lightweight design, which makes the unit easier to use and easier to carry from job to job, is said to have been achieved without affecting the machine's cutting capacity or ruggedness.



An exclusive new three-point precision suspension system reportedly increases the cutting accuracy of the machine and greatly improves the quality of finished jobs.

The new Cut-O-Matic No. 7 may be had with either 110- to 115-v a-c, d-c or 220 a-c motor, standard or slow speed. National Cylinder Gas Co., 840 N. Michigan Ave., Chicago 11, Ill.

Regulators

The K-G Equipment Co., Inc., of Allentown, Pa., announce their new line of "On Guard" Regulators. The manufacturer states that it is a completely new type, designed to virtually eliminate internal and external regulator repairs.

The regulator has a patented gage guard with a positive spring lock action, protecting the gage from accidental breakage. A stainless steel nipple is designed to withstand the impact of accidental cylinder upset. A newly designed stainless steel adjusting screw, according to the manufacturer, eliminates the possibility of its becoming damaged. The pressure adjustment is stated to be a smooth, easy action developed by means of a completely enclosed thrust bearing, integral with the adjusting mechanism.

A new bulletin, with detailed information, is available from the manufacturer.

Resistance Welding Control

A new line of resistance welding controls, featuring printed circuits and a weld-safe circuit for the protection of equipment and work in process, is available from the Westinghouse Electric Corp. Circuit components and tubes have been reduced to the minimum number necessary for proper functioning. This circuit simplification combines with the use of printed circuits to reduce panel weight by 30%.

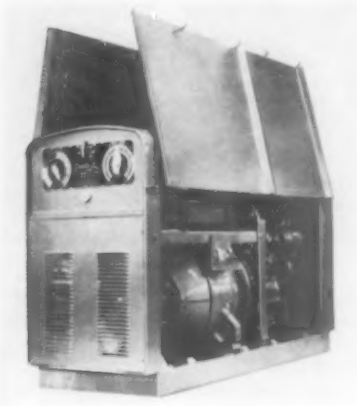
The weld timer and sequencing circuit is designed to lock out welding current should tube failure occur at any time.

For further information on this new line of controls, write Westinghouse Electric Corp., P. O. Box 2099, Pittsburgh 30, Pa.

Diesel Driven Welder

A new Diesel-powered welder for construction, pipe line and structural welding has been announced by the Lincoln Electric Co. of Cleveland, Ohio. The welder, called the "Shield-Arc SAE-250," is rated 250 amp at 40 v, 60% continuous duty cycle. It features Diesel-powered welding capacity in a relatively compact, low-cost design. It weighs approximately 20% less, is 1 ft shorter in length and costs 25% less than a comparable 300-amp welder.

It has a range of 50 to 250 amp, handling electrodes from $^1/_{16}$ to $^1/_4$ in. diam.



An improved fuel system of the engine maintains accurate current output both in arc striking and throughout the range of the welder. The welding generator is equipped with power outlets to provide 115 v, d-c auxiliary power for operating tools and lights.

The welder is powered by a new Diesel engine, the DIX-4D, developed by the Hercules Motor Corp. of Canton, Ohio. This is a 4-cylinder, 4-cycle engine with 166 cu in. displacement, rated at 39 hp at 1700 rpm. It is equipped with a 12-v starting motor and an ether injection system for cold weather starting.

For additional information, write directly to the Lincoln Electric Co.

Gamma Ray Projector

A portable gamma ray projector that is claimed to have decided advantages over conventional X-ray equipment used in radiography work has been placed on the market by the M. W. Kellogg Co.

The projector is being made in three sizes, 75, 250 and 2900 lb. It will be marketed through Kellogg's recently formed Nuclear Products Division. Exclusive sales agent is Metal & Thermit, New York.

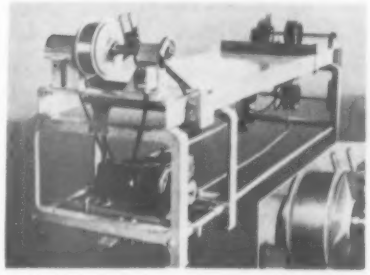
According to the manufacturer, the gamma ray projector is extremely safe to operate, costs only a fraction as much

as comparable X-ray equipment that is used for radiography work, is extremely portable, needs no electricity, no control board, no maintenance beyond replenishment of the radioisotope, and can take a picture of 360 deg.

For additional information write to Metal & Thermit, 100 E. 42 St., N. Y. 17.

Microspooling Machine

A new and revolutionary machine has been announced by the Boyd & Sons Manufacturing Co. It is used for level layer winding weld wire as used in the metal inert-gas-shielded arc-welding processes.



Known as the Boyd Microspooler, it requires no gear changeovers, yet provides adequate controls in the efficient level layer winding of all existing alloys of weld wire.

Information on this spooler or a demonstration can be had by contacting Boyd & Sons Manufacturing Co., 1434 Callowhill St., Philadelphia 30, Pa.

Constant-Voltage Welders

Just announced is a new line of constant-voltage welders, which the manufacturer claims will make welding operations more efficient while producing better welds with fewer rejects.

The Harnischfeger Corp., Milwaukee, Wis., is offering a new line of 500, 750 and 1200-amp Constant-Voltage Welders which allow the operator to select the arc voltage he desires. This voltage then remains constant during the entire welding cycle. All the operator must do is set the correct rod feed and travel rate to get the desired deposit rate. The constant voltage feature insures that the deposit is uniform; arc voltage, rod speed and travel rate all remain constant.

More information is available by writing the company or by contacting the Harnischfeger Corp., Milwaukee 46, Wis.

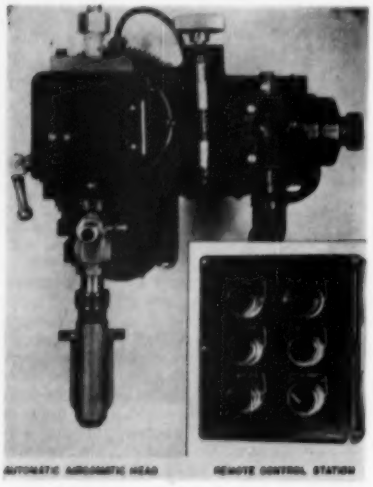
MORE AND MORE WELDERS
are turning to
HI-AMP
PRODUCTS EVERYDAY
and here's why—

First of all they are built for outstanding performance on any hand welding job — and second because they are priced right — thus giving extra value regardless of model. Just check the new PI-5 for instance, against competing 500 Amp. holders — and you've got the answer. And that's equally true of HI-AMP Products through the entire line.

Sold only through Welding Supply Distributors in the U. S. and Canada.
WAGNER MFG. CO.
350 W. 1st SOUTH ST.
JACKSON, MISSOURI
Weld with Wagner

Automatic Welding Unit

A new automatic welding head for gas metal-arc welding has been placed on the market by Air Reduction.



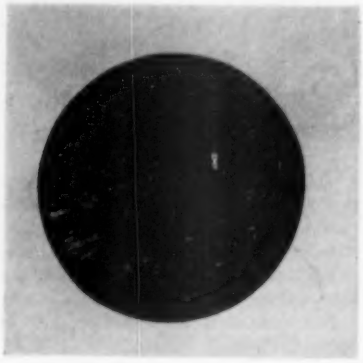
Argon, carbon dioxide and helium shielding gases and all kinds of welding wires (steel, aluminum, bronzes, stainless and Strandalloy), from 0.030 in. in diameter and up, can be used.

Compact in design, the new head has a continuous current rating of 600 amp.

For more information, write Air Reduction Sales Co., 60 E. 42nd St., New York 17, N. Y.

Hard-Facing Welding Wire

The development of a new fabricated welding wire has just been announced by the Drawalloy Corp., York, Pa. Wear-O-Matic, the new fabricated wire is specifically for automatic and semi-automatic hard-facing applications. It is said to be the first of its kind on the market.



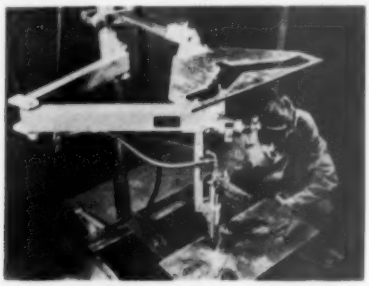
As the accompanying cross-sectional illustration shows, Wear-O-Matic is a dense, controlled-diameter wire. It has a uniform compactness for uniform chemistry and hardness. According to officials of the Drawalloy Corp., new Wear-O-Matic fabricated wire is precision drawn to provide a smooth feed with any automatic head without the use of special feed rolls or contact tubes.

As the final step in the production of Wear-O-Matic wire, it is electroplated with copper. This, the company indicates, is done to prevent surface rust and to insure positive electrical contact.

For more information on new Wear-O-Matic fabricated welding wire, including a free sample specimen, write: Dept. *WJ*, Drawalloy Corp., York, Pa.

Cutting Machine

A new flame-cutting machine featuring a permanent magnetic roller has been introduced to the metalworking public by Air Reduction.



Designated as No. 42 Camograph, it cuts any shape up to a full 42-in. circle and straight lines to 92 in. It is portable and will shape-cut any practicable thickness.

For more information about the new Airco No. 42 Camograph, write Air Reduction Sales Co., 60 E. 42nd St., New York 17, N. Y.

INDEX TO ADVERTISERS

Air Reduction ..... Outside back cover
Alloy Rods 1109
Aluminum Co. of America 1132, 1133
American Chain and Cable 1143
Ampco Metal Inc. 1131
Armour Research Foundation 1106
Aronson Machine Co. 1138

Becker Bros. Carbon Co. 1124

Convair 1106

Dockson Corporation 1140
Drawalloy Corporation 1147

Erico Products, Inc. 1142

Fibre-Metal Products Co. ..... Inside front cover

General Electric 1120, 1121
General Electric—Tube Department 1117
General Split Corporation 1149

Hobart Brothers Company 1057

International Nickel 1062

Jackson Products, Inc. ..... Inside back cover

V. E. Kennedy-Ingalls Co. 1148

Lincoln Electric Company 1115
Linde Air Products Company, a Division of Union Carbide and Carbon Corp. 1060

P. R. Mallory & Co., Inc. 1059
Metal & Thermit Corporation 1058
Miller Electric Manufacturing Co. 1113
Modern Engineering Co. 1145

National Carbide Company 1105
National Cylinder Gas Co. 1123
National Welding Equipment Co. 1125

Page Steel and Wire Division 1143
Progressive Welder Sales Co. 1137
Pure Carbonic Company 1134, 1135

A. O. Smith Corporation 1128, 1129

Solar Aircraft Company 1106
Square D Company 1139
Stulz-Sickles Co. 1110
Sylvania 1111

Tempil® Corporation 1064
Tweco Products Company 1150

Union Carbide and Carbon Corporation
Linde Air Products Company 1060
United States Testing Company, Inc. 1112

Vickers Electric Div., Vickers, Inc. 1141

Wagner Mfg. Co. 1151
Westinghouse Electric Corp. 1106, 1112, 1124

W. SPRARAGEN, DIRECTOR

WRC

WELDING RESEARCH COUNCIL

OF THE ENGINEERING FOUNDATION

SUPPLEMENT TO THE WELDING JOURNAL, NOVEMBER, 1955

SEAM WELDING DISSIMILAR THICKNESSES OF LOW-CARBON STEEL

Proper welding conditions for the fabrication of pressure tight, seam-welded joints in dissimilar thickness combinations of low-carbon steel sheets determined through laboratory investigation

BY M. L. BEGEMAN AND E. J. FUNK

This paper makes available the results of an investigation conducted to determine proper welding conditions for the fabrication of pressure-tight, seam-welded joints in dissimilar thickness combinations of low-carbon steel sheets. The research was carried out under the auspices of the Resistance Welding Committee of the Welding Research Council, representing one phase of an extensive investigation of seam welding sponsored by the Resistance Welder Manufacturers' Association.

Purpose of Investigation

The purpose of this study was to develop two sets of welding schedules for the several combinations of the three sheet thicknesses. One schedule was to be at the normal welding speed for easy handling of weldments—a speed which provided close control of welding variables for high quality welds. The other schedule was to be for faster welding speeds so often desired in production work. The speed of the latter schedule in each case is approximately twice the normal schedule. These speeds all closely approach the maximum possible welding speeds from the standpoint of manual operation.

In working out these schedules the following criteria established by the Resistance Welding Committee were observed:

1. The weld nugget penetration in the thinner sheet should be not less than 20% or greater than 80%.
2. Porosity in the weld nugget should be at a minimum.
3. There should be sufficient overlap of the weld nuggets to produce a leak-proof joint.

These criteria were selected to meet the requirements of the basic applications of seam welds; that is, they should be strong when submitted to a shearing stress and pressure tight when made in container assemblies. The combinations for which schedules were determined at the two speeds are 0.031 in. with 0.078 in., 0.031 in. with 0.050 in. and 0.050 in. with 0.078 in.

Equipment and Material

The welding was accomplished by means of a 250-kva circular seam welder equipped with an electronic control unit.* Electrodes were of RWMA Class 2 alloy, 10 in. in diameter and $^1/_2$ in. thick with the edges beveled at 15° to accommodate the friction drive wheels.† The entire investigation was carried out using electrodes having a $^1/_4$-in. face width and a face radius of 6 in. A pointer stop ammeter measured the welding current and the electrode force was measured with an electrode force gage.

The material used was low-carbon, pickled and oiled, hot-rolled, rimmed steel commonly designated as SAE 1010.‡ Three thicknesses used were of the following analyses:

Thickness, in.	*C, %*	*Mn, %*	*P, %*	*S, %*
0.031	0.08	0.39	0.008	0.029
0.050	0.07	0.41	0.012	0.037
0.078	0.08	0.39	0.010	0.034

Seam Welding Variables

The major variables in seam welding can be broken down into two general classifications: (1) those associated with time, which are welding speed and current pattern (heat time and cool time); and (2) those associated with heating, which are current magnitude and electrode force. The factors which tend to effect the selection of the time variables are the ability to handle the parts while welding, the necessity of producing overlapping weld nuggets to insure pressure-tight joints and electrode pickup that results from surface melting. The heat generated in seam welding is the result of a current passing through the resistance offered

M. L. Begeman is Professor of Mechanical Engineering, and **E. J. Funk** is Graduate Student, RWMA Fellowship, University of Texas, Austin.

Presented at 1955 AWS National Fall Meeting in Philadelphia, Pa., Oct. 17–21, 1955.

* The seam welder and electronic control were furnished by RWMA.

† Electrodes were furnished by P. R. Mallory & Co.

‡ The sheet steel used in this work was supplied by the United States Steel Co.

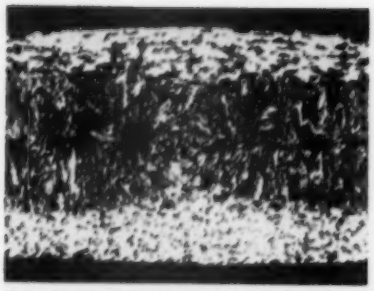


Fig. 1 Longitudinal section of a seam weld made in 0.031- to 0.050-in. low-carbon steel showing the effect of a low ratio of heat time to cool time (3 cycles cool time and 2 cycles heat time); X 17

by the contacts between the electrodes and the surfaces of the materials being welded, the resistance of the materials being welded and the contact resistance offered at the interface of the pieces being welded. The heat generated at the electrode contact surface is kept at a minimum by the use of copper-alloy electrodes and is dissipated by flooding the electrodes and weld area with a cooling medium. In this case water served exclusively as the coolant. The other two sources of heating are employed in raising the metal to the welding temperature. Fortunately, the heating due to the resistivity of the metal is small and the major portion of the useful heating is caused by the contact resistance at the interface of the materials. The magnitude of the heat generated can be controlled either directly by increasing or decreasing the current; or inversely by increasing or decreasing the electrode force which in turn affects the contact resistance. Thus, the reason for classifying the current and electrode force as heat-associated variables is explained.

The factors which influence the selection of heat-associated variables are the desired penetration which is related to the strength of the weld, the occurrence of porosity and, to some extent, nugget overlap and surface conditions of the finished weld.

Procedure

The procedure employed in establishing seam welding schedules is as follows:

1. Since the objective of the investigation was to establish schedules for two levels of speed, the lower speed was selected as a value corresponding to a practical working value for welding the thinner sheet from "Recommended Practices," and the higher speed was chosen to be roughly twice the lower value.

2. The selection of a speed then somewhat narrowed the range of choice left for cycling to combinations already proved feasible for the lower range and to combinations with very short cool times for the higher range. In each case a number of tests were made varying the heat and cool times and with the remaining variables at the accepted values for welding the thinner sheet. These samples were examined and the best timing pattern chosen was the one which came closest to satisfying the requirements for an acceptable seam weld.

3. Once the time-associated variables were established, a thorough investigation of the relationship of current magnitude and electrode force was made to determine the amount of heat required to produce an acceptable weld. This was done by allowing the current to vary over a wide range for several values of electrode force. Each weld was subjected to X-ray and metallurgical examination, and the selected schedule values made according to the criteria already discussed.

4. The selected variables were then confirmed by means of "pillow" tests. This test is a hydrostatic one in which two sheets (6 x 6 in.) were seam welded around the edges and subjected to hydrostatic pressure until failure occurred. In each case, failure occurred on an inside edge of the seam where the bending stresses were greatest due to the expansion of the test sample. This type of failure, around rather than through the weld, indicated that the weld was satisfactory and pressure tight. Other than indicating that the seam was leak tight, this test was of little use. Bursting pressure varied widely depending on the shape developed by the expanding pillow.

FORCE, LBS / CURRENT, AMPS	WELD NUGGET PENETRATION, % 500	600	700	800	900
12,000	18	8			
13,000	32	18			
14,000	34	24	7		
15,000	47	37	15	10	
16,000	41	44	25	20	17
17,000	57	41	33	23	18
18,000	55	48	33	23	18

▨ — WELD WITH POROSITY
□ — INDICATES NO POROSITY

Fig. 2 The relationship of weld porosity to seam welding variables of current, electrode force and penetration into the thinner sheet of a 0.031- to 0.078-in. unequal thickness combination of low-carbon steel. Welds were made at a speed of 72 ipm with 3 cycles heat time and 2 cycles cool time

Time-Associated Variables

The speed of welding is related to the total time of the cycling pattern in such a manner as to limit the actual

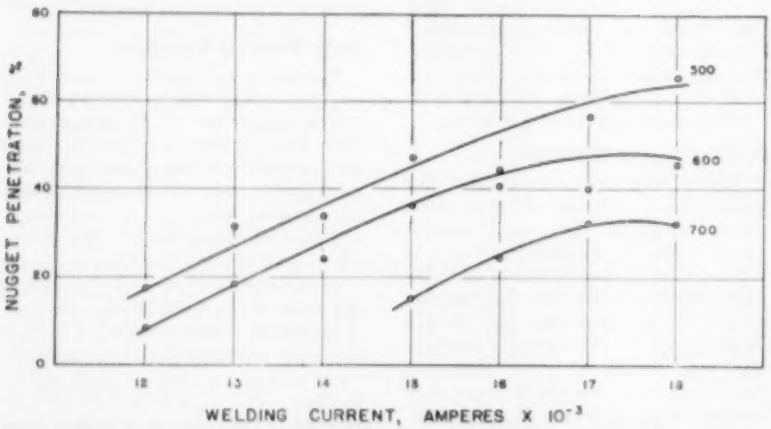


Fig. 3 The influence of welding current on penetration at several values of electrode force in welds made of a 0.031- to 0.078-in. unequal thickness combination of low-carbon steel. Welding speed was 72 ipm with heat time of 3 cycles and 2 cycles cool time

FORCE, LBS / CURRENT, AMPS	WELD NUGGET PENETRATION, % 700	800	900	1000	1100
18,000	9	12			
19,000	17	22	5		
20,000	29	30	15	10	
21,000	35	36	21	19	8
22,000	48	47	27	28	14
23,000	52	53	38	36	22
24,000	58	55	37	31	30

▨ — REGULARLY RECURRING POROSITY
▨ — OCCASIONAL POROSITY
□ — INDICATES NO POROSITY

Fig. 4 The relationship of porosity and penetration to machine settings of current and electrode force for seam welding a combination of 0.031- to 0.078-in. steel at a speed of 142 ipm. Heat time 2 cycles with a cool time of 1 cycle

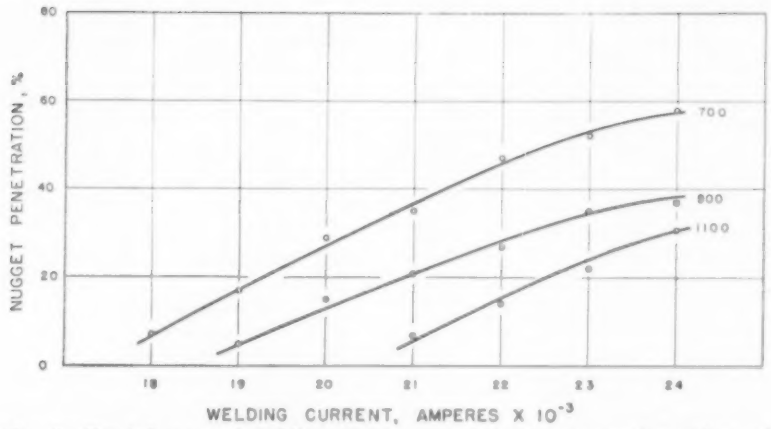


Fig. 5 The influence of welding current on penetration at varying values of electrode force for welds made in a 0.031- to 0.078-in. combination of low-carbon steel. Welding speed was 142 ipm with heat time 2 cycles and cool time 1 cycle

FORCE, LBS. / CURRENT, AMPS	WELD NUGGET PENETRATION, % 600	700	800	900	1000
13,000	28	13			
14,000	39	25	16		
15,000	40	37	24		
16,000	36	46	31	16	10
17,000	53	56	46	32	20
18,000		60	52	40	33
19,000			56	43	41
20,000				51	43
21,000					47

▨ — REGULARLY RECURRING POROSITY
□ — OCCASIONAL POROSITY
□ — INDICATES NO POROSITY

Fig. 6 The relationship of porosity and penetration to seam welding variables of current and electrode force in a combination of 0.031- and 0.050-in. low-carbon steel. Heat time 3 cycles, cool time 2 cycles and a speed of 72 ipm

choice of a heat and cool time combination to a somewhat narrow range determined by the thickness of the material being welded. In general, as the sheet thickness decreases, the number of weld nuggets per inch increases. In the case of welding 0.050 to 0.078-in. steel at a speed of 60 ipm, it was found that 8.6 nuggets per inch would yield consistent overlap, while in welding 0.031 to 0.050 in. at 72 ipm, 10 nuggets per inch were required. For the lower speed schedules the ratios of heat to cool time that yielded the best results were greater than 1.25 to one and less than 2 to 1. Figure 1 shows the effect of allowing the ratio of heat to cool time to fall below 1.25 (in this case 0.67 to 1). When the spacing is greatly increased one can observe a negative overlap which is known as roll spot welding. The cycling patterns for welding dissimilar thickness combinations at lower speeds were found to be in good agreement with published values for welding the thinner sheet, which seems reasonable since the speeds were selected from these same sources. However, it was found that at higher speeds the difficulty encountered in obtaining overlapping nuggets made it necessary to use ratios of heat to cool time of from 2 to 1 to as high as 3 to 1. The choice of cycling at higher speeds becomes a matter of choosing as short a cool time as possible and picking the shortest heat time that will yield nugget overlap. This gives the largest possible number of nuggets to the inch which will yield leak-tight welds.

Heat-Associated Variables

As was previously stated under procedure, once the speed and cycling pattern were determined, a detailed study of the effect of current and electrode force variation was made to establish the amount of heat that was necessary to produce an acceptable weld. The results of this phase may be observed in Figs. 2 through 13 which show the range of current and electrode force investigated and the relationship to porosity and penetration. Three types or classifications of porosity were found to occur as revealed by X-ray examination: (1) a regularly recurring porosity associated with each spot as is shown at the top of Fig. 14; (2) an occasional or nonuniform porosity, shown in the center radiograph; and (3) as shown in the lower radiograph, optimum state of no porosity. The occurrence of porosity appears to be related to the amount of penetration found in the weld. The lowest heat welds showing regularly recurring porosity even before appreciable penetration is observed. Figure 15 shows a longitudinal section of a weld in 0.031 to 0.050-in steel which has uniform

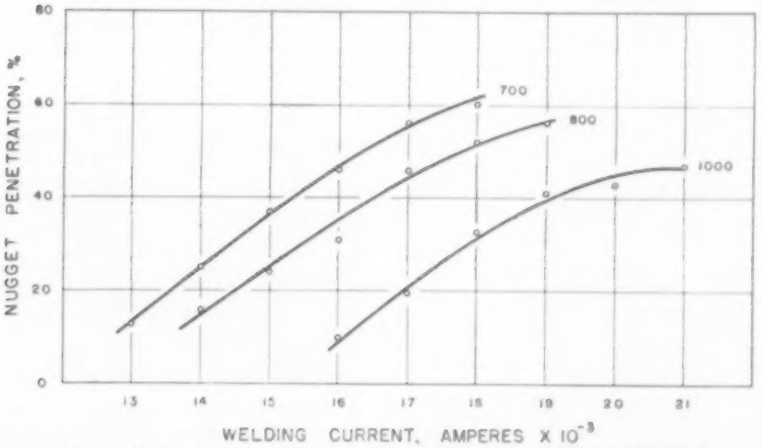


Fig. 7 The effect of welding current on penetration at several values of electrode force for welds made in 0.031- to 0.050-in. unequal thickness combinations of low-carbon steel. Welding speed was 72 ipm, heat time 3 cycles and cool time 2 cycles

FORCE, LBS. / CURRENT, AMPS	WELD NUGGET PENETRATION, % 600	700	800	900	1000
16,000	46	30	28		
17,000	51	28	30	31	30
18,000	60	44	35	33	35
19,000	66	55	46	38	34
20,000	72	57	47	41	36
21,000		66	58	47	45
22,000		75	68	57	46
23,000				60	58
24,000					66

▨ — REGULARLY RECURRING POROSITY
□ — OCCASIONAL POROSITY
□ — INDICATES NO POROSITY

Fig. 8 The relationship of porosity and penetration to seam welding variables of current and electrode force in a combination of 0.031- to 0.050-in. low-carbon steel. Heat time 2 cycles, cool time 1 cycle, and at a welding speed of 142 ipm

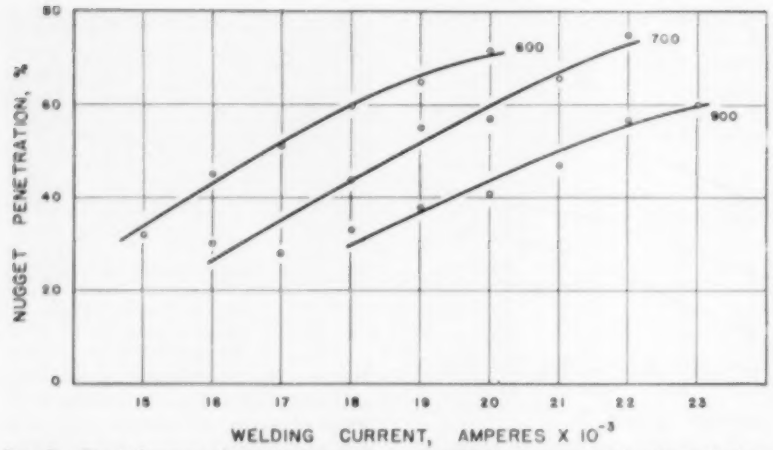


Fig. 9 The influence of welding current on penetration at several values of electrode force for welds made in 0.031- to 0.050-in. combinations of low-carbon steel. Welding speed was 142 ipm with heat time 2 cycles and cool time 1 cycle

porosity and the thinner sheet shows no measurable penetration. An idea of the relative sizes of the two sheets can be gained by noting the interface line between the two pieces.

As has been previously mentioned, the amount of heat generated in the weld can be controlled by varying the current, or to a lesser degree by varying the electrode force which in turn affects contact resistance. A combination of high current and high electrode force will tend to have the same resulting metallurgical structure as a combination of low current and low electrode force. In other words, metallurgical examination reveals the condition under which the weld was made with regard to whether the weld was "hot" or "cold," but it cannot distinguish between the principal contributing factors that generated the heat. The micrographs shown in Fig. 15, 16 and 17 illustrate the effect of increasing the amount of heat used to make the weld. In this case the electrode force for each weld was 800 lb, and the current used was 13,000 amp in Fig. 15, 16,000 amp in Fig. 16, and 19,000 in Fig. 17. A similar but not so pronounced effect would be observed if the welds in Fig. 15, 16 and 17 had all been made at 16,000 amp and the electrode force varied such that Fig. 15 would have been welded with a very high electrode force and the other two at progressively lower forces. Thus, it may be said that for any practical combination of time-associated variables, a large number of combinations of current and electrode force exist that will generate enough energy at the interface to satisfactorily accomplish the welding.

The selection of the proper electrode force limits the current which can be successfully used to fabricate satisfactory joints. From a standpoint of penetration, its selection is a matter which is somewhat arbitrary as might

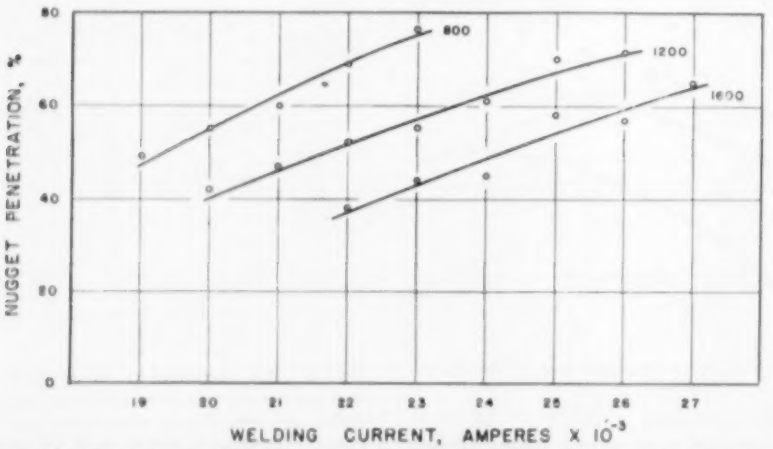


Fig. 11 The influence of current on penetration at several values of electrode force for seam welding 0.050- to 0.078-in. low-carbon steel at a speed of 60 ipm with 4 cycles heat time and 3 cycles cool time

FORCE, LBS / CURRENT, AMPS	WELD NUGGET PENETRATION, % 800	1000	1200	1400	1600
19,000	49	22			
20,000	55	45	42		
21,000	60	66	47	41	
22,000	69	57	52	45	38
23,000	77	73	55	50	44
24,000		76	61	53	45
25,000			70	51	58
26,000			72	69	57
27,000					65

▨ — REGULARLY RECURRING POROSITY
□ — OCCASIONAL POROSITY
□ — INDICATES NO POROSITY

Fig. 10 The relationship of porosity and penetration to machine settings of current and electrode force as observed in welding 0.050- to 0.078-in. low-carbon steel at a speed of 60 ipm with 4 cycles heat time and 3 cycles cool time

be concluded from studying Fig. 3, 5, 7, 9, 11 and 13. However, with low electrode forces, small current variations have considerable influence on weld quality. It is therefore advisable to use electrode forces of sufficient magnitude to permit higher current variation. No schedules using electrode forces less than 500 lb were included in this investigation.

These curves, all of which show the effect of welding current on penetration for different speed and thickness combinations, are similar in their shape. They graphically portray the amount of increase in nugget penetration for increased welding currents and also indicate the effect of varying electrode forces on penetration. Data for these curves may be found on the accompanying figure in chart form.

The data present in Figs. 2, 4, 6, 8, 10 and 12 are presented in chart form and indicate the effect of cur-

FORCE, LBS / CURRENT, AMPS	WELD NUGGET PENETRATION, % 800	1000	1200	1400	1600
17,000	39				
18,000	44	40			
19,000	50	46	32		
20,000	62	48	36	19	
21,000	58	52	38	29	17
22,000	67	58	41	42	21
23,000		67	55	33	28
24,000			56	41	29
25,000			60	48	35
26,000					43

▨ — REGULARLY RECURRING POROSITY
□ — OCCASIONAL POROSITY
□ — INDICATES NO POROSITY

Fig. 12 The relationship of porosity and penetration to machine settings of current and electrode force as observed in welding 0.050- to 0.078-in. low-carbon steel at a speed of 120 ipm with 3 cycles heat time and 1 cycle cool time

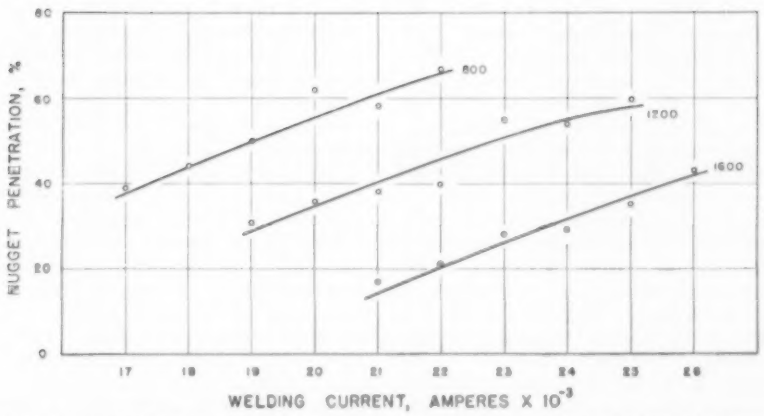


Fig. 13 The effect of current on penetration at varying values of electrode force for seam welding 0.050- to 0.078-in. low-carbon steel at a speed of 120 ipm with 3 cycles heat time and 1 cycle cool time

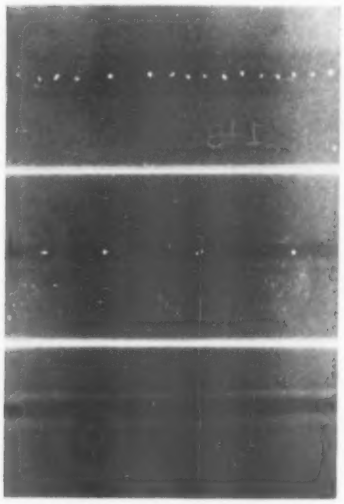


Fig. 14 Prints from radiographs of welds in 0.031- to 0.050-in. steel showing at top regularly recurring porosity, in the center occasional or nonuniform porosity, and at the bottom a weld which represents the optimum condition of no porosity

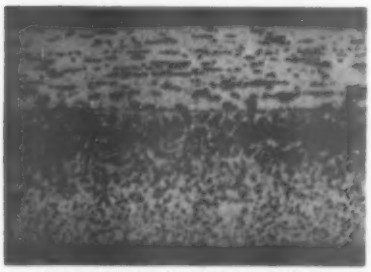


Fig. 15 Longitudinal section of a seam weld in 0.031- to 0.050-in. steel showing the occurence of uniform porosity before appreciable penetration can be measured. Note the interface between the two pieces; X 17

rent and electrode force on both penetration and weld nugget porosity. It should be noted that these figures indicate conditions which produce welds with little or no porosity, conditions which produce only occasional porosity and finally, those conditions at which the porosity occurs at fairly close, regular intervals. The weld nugget pentration figures indicate the penetration into the thinner sheet.

The results shown in these latter figures all indicate a loss in penetration and a slight gain in porosity as the electrode force is increased. There is also some difficulty in starting a weld when using a high electrode force and a high current value. This may be due to a slight time lag between the time the electrodes contact the work and when the electrode force actually reaches its specified value. During this period the low electrode force, high current and high contact resistance combine to produce sufficient heat to cause "flashing," "burning through" and undesirable defects. If the seam could be started at the end of a previous seam much of this would be eliminated. In reviewing these curves it appears that an electrode force value somewhere near the middle of the range represents a reasonable compromise and results in good welds having desirable characteristics.

After the selection of a reasonable value of electrode force, a number

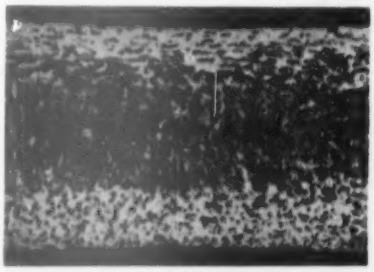


Fig. 16 Longitudinal section of a seam weld made in 0.031- to 0.050-in. steel showing low penetration into the thinner sheet (top); X 17

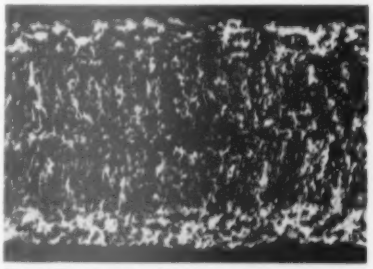


Fig. 17 Longitudinal section of a seam weld made in 0.031- to 0.050-in. steel showing a high degree of penetration into the thinner sheet (top); X 17

THICKNESS (INCHES)		WELDING SPEED (INCHES PER MIN.)	CURRENT (AMPERES)	TIMING CYCLE (CYCLES)		ELECTRODE FORCE (POUNDS)
THIN SHEET	THICK SHEET			HEAT	COOL	
0.031	0.078	72	16,000	3	2	600
0.031	0.078	142	22,000	2	1	800
0.031	0.050	72	17,000	3	2	800
0.031	0.050	142	20,000	2	1	700
0.050	0.078	60	22,000	4	3	1200
0.050	0.078	120	22,000	3	1	1200

Fig. 18 Recommended machine settings for welding dissimilar thickness combinations of 0.031-, 0.050- and 0.078-in. low-carbon steel at two levels of speed

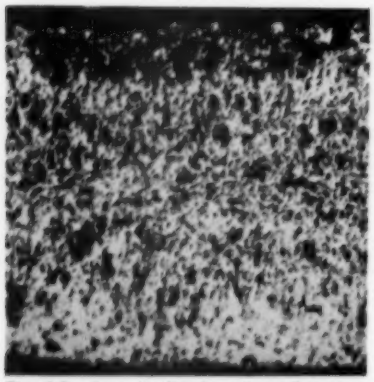


Fig. 19 Longitudinal section of a seam weld made in 0.031- to 0.078-in. low-carbon steel at the recommended settings of Fig. 18 for a speed of 72 ipm; X 17

of conditions combine to direct the choice of current magnitude. At low values of current there is porosity and low penetration. However, if the current is increased too much the weld suffers from surface burning and other effects of overheating. The prescribed limits of penetration unfortunately overlap both ends of the current range and so a selection of current on a basis of meeting only the penetration requirements would not represent the best solution to the problem. It remains then that a current must be selected somewhere above the range in which low heating produces poor welds and below the range in which undesirable overheating effects take place. This selection can be made with the aid of the information presented in Figs. 2 through 13.

Conclusions

The resulting seam-welding schedules based upon the foregoing procedure and discussion are shown in Fig. 18. This schedule indicates the current, speed, timing cycle and electrode force for each of the thickness combinations investigated. It is concluded that the use of these machine settings will yield pressure-tight welds of consistent penetration and nugget overlap. A minimum of porosity should be obtained and all welds should possess acceptable surface appearance. To obtain these results it is assumed that reasonable care is taken in cleaning the metal surfaces prior to the weld so as to remove the influence of oil and dirt inclusions.

A study of the typical structures obtained in welds made at the recommended low speed values for thickness combinations of 0.031 to 0.078 in., 0.050 to 0.078 in. and 0.031 to 0.050 in. are shown, respectively, in Figs. 19, 20 and 21. The columnar dendritic structure is characteristic of the penetration zone in all of the welds made at slow to moderate speeds.

As a contrast to the structure observed in lower speed welds, Fig. 22 illustrates the confused and disarranged pattern of a high-speed weld made in the same unequal thickness combination as Fig. 21. The only occurrence observed in the course of the investigation that was peculiar to the problem of welding dissimilar thicknesses was the centering of the heat affected zone about the geometric center of the composite thickness of the two pieces being welded instead of at their interface. This occurs in all the micrographs and is most strikingly observed in Fig. 15. This micrograph shows a cold weld in which the porosity and miniature nuggets are entirely within the confines of the thicker sheet. This offsetting of the nugget had no serious effect as far as the thickness combinations were concerned, but it would seem reasonable to anticipate that in cases, where the ratio of the thinner sheet to the thicker sheet became very small, some difficulty in obtaining sufficient penetration might be experienced. This offsetting is due to an uneven heat balance condition created by having unequal sheet thicknesses and can be controlled to some extent by adjusting the flow of cooling water so that the thicker piece is cooled more thoroughly or by different width electrodes.

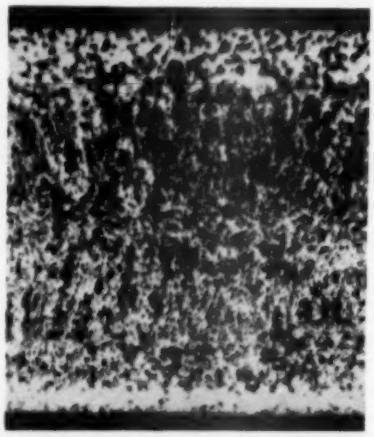


Fig. 20 Longitudinal section of a seam weld made in 0.050- to 0.078-in. low-carbon steel at the recommended settings of Fig. 18 for a speed of 60 ipm; X 17

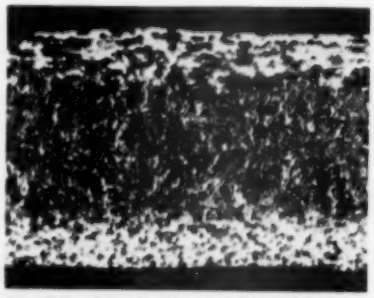


Fig. 21 Longitudinal section of a seam weld made in 0.031- to 0.050-in. low-carbon steel at the recommended settings of Fig. 18 for a speed of 72 ipm. Note the occurence of the typical columnar dendritic structure; X 17

Reference to all the curves in chart form (2, 4, 6, 8, 10 and 12) will indicate that the tendency for nugget porosity is increased by decreasing the heat in the weld. This is contrary to the general statement, "Internal defects in spot, seam and projection welding are generally caused by low electrode force, high current or any other conditions which produce excessive weld heat."* In discussing this phenomenon it can be assumed that practically all resistance weld nuggets have those conditions which tend to produce a shrinkage cavity. If a cavity is formed in a cold weld it usually remains as the surrounding plastic area is small and the electrode force is incapable of forging it shut or diffusing it with the surrounding metal. However, with high heat and high penetration there is sufficient plasticity in the weld nugget to respond to the forging action of the electrodes. When sufficient penetration in the welds was obtained no higher heat schedules were checked.

In so far as the welding process itself is concerned there is one advantage of using unequal sheet thicknesses of metal. The use of a thinner sheet will allow a greater welding speed than could be employed if the combination consisted of two thick sheets. It was found that a combination of 0.031 and 0.078-in. sheets could be successfully welded at a speed of 142 ipm, while the near maximum speed for welding two pieces of 0.078-in. sheet was 100 ipm. It was also observed that the process of seam welding becomes increasingly difficult to control as welding speeds approach the higher values. High-speed schedules should be avoided if weld quality is a prime requisite.

* *Welding Handbook*, 3rd ed., p. 948

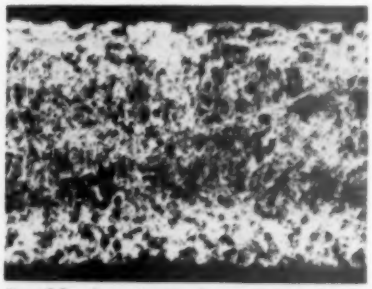


Fig. 22 Longitudinal section of a seam weld made in 0.031- to 0.050-in. low-carbon steel at the recommended settings of Fig. 18 for a speed of 142 ipm. Note the structure which is typical of welds made at high speed; X 17

LITHIUM ADDITIONS TO BRAZING ALLOYS

Results of experimental investigation indicate that lithium is a most suitable metal for developing self-fluxing brazing alloys

BY N. BREDZS AND D. CANONICO

ABSTRACT. By comparing some chemical and physical properties of lithium with the properties of some other strongly deoxidizing metals, it is shown that lithium appears to be the most suitable metal for developing self-fluxing brazing alloys. The wettability tests performed with molten 1% Li–99% Ag alloy on low-carbon steel, drill rod and 303 stainless steel confirm this theoretical postulation. Small additions of lithium not only reduce the oxides on the surfaces of these steels, but also considerably lower the wetting (contact) angle of molten silver thus promoting wettability and fluidity. The lithium bearing silver alloys and the lithium bearing copper alloys should prove useful for brazing plain carbon steels, as well as stainless steel without flux or reducing atmospheres. The tensile strength of such joints is quite high. Preplaced lithium bearing silver alloys and lithium bearing copper alloys should torch braze stainless steel in air without fluxes.

Introduction

An effective brazing flux has three principal functions:

1. To dissolve any oxides present on the base metal surfaces which are to be brazed.
2. To prevent the oxidation of these surfaces during the brazing process.
3. To lower the surface tension of the molten filler metal, thus promoting wetting of the base metal by the molten filler metal.

If a flux can fulfill these three basic requirements, good wettability of the base metal by the molten filler metal will not cause any problems, and a rapid flow of the molten filler metal in the capillary gap will be assured.

In recent years brazing fluxes have been replaced to some extent by reducing atmospheres, especially in high-temperature brazing. Since the reducing atmospheres reduce metallic oxides only at higher temperatures, they can not be used for low-temperature brazing or soldering. At higher temperatures, however, the reducing atmospheres take over the functions of a brazing flux, namely: they reduce the oxides on the base metal surfaces and prevent these surfaces from oxidizing during the entire brazing process.

Considering the surface tension of the molten filler metal, it can be assumed that under a reducing atmosphere the surface tension will not be appreciably altered and will be practically the same as under a neutral atmosphere (nitrogen, helium, etc.) or, in vacuum, provided that in all cases the surface of the liquid filler metal is free from oxides. The surface tension of the molten filler metal might be influenced by the reducing atmosphere only indirectly. For instance, the surface tension of the molten filler metal might be considerably altered during the reducing process, when the reducing atmosphere makes the surface completely free from oxides.

Industrial brazing practice shows that in numerous instances, as, for example, in brazing of stainless steels, neither brazing with fluxes nor reducing atmospheres yield completely satisfactory results.

When brazing stainless steel with fluxes, the removal of fluxing compounds, expecially in large articles may present difficulties. The comparative viscosity of fluxes saturated with metal oxides may inhibit the penetration of the filler metal into joints with small clearances. When this occurs the resultant joints are of poor uniformity and strength.

In a reducing atmosphere, however, at practical brazing temperatures stainless steel is subject to heavy oxidation if the atmosphere contains even the smallest amounts of water vapor. Therefore, brazing of stainless steel without flux is usually confined to small articles that are protected from oxidation by very dry hydrogen having a dew point of −40° F or below.

Some of the difficulties in the field of brazing stainless steels may be illustrated by the fact that to obtain more sound and stronger brazed joints, plating of a thin coating of iron on stainless steel surfaces has been tried and subsequently applied in practice.[1]

As this short résumé shows, it would be very helpful and would represent worthwhile progress, especially in the field of brazing alloy steels and stainless steels, if it were possible to develop self-fluxing brazing alloys that would include constituents capable of reducing the base metal oxides. These alloys could be used without any fluxes or reducing atmospheres. The idea of preparing self-fluxing brazing alloys is not quite novel. Copper-phosphorus and silver-copper-phosphorus brazing alloys have been used in industry for many years. When these alloys are used on copper or some copper rich alloys, no flux or reducing atmospheres are necessary. During the brazing process, phosphorus oxidizes partly by reduction of the oxides present on the surface of the copper on which the brazing alloy flows. The fusible slag resulting from this reaction takes the place of the flux which is normally added.

However, the brazing alloys containing large amounts of phosphorus cannot be used on ferrous materials, nickel, or alloys containing appreciable amounts of nickel, because of the brittle phosphides. Thus, one strong deoxidizer, namely, phosphorus, cannot be used as a deoxidizing addition to self-fluxing brazing alloys for brazing of steels.

In the search for the most suitable and effective deoxidizing additions for self-fluxing brazing alloys, first of all it has to be considered that it might be comparatively easy to reduce iron oxides, but it is much more difficult to reduce oxides of some alloy steels, especially the ones which produce on the surfaces heavy reducible oxides, such as chromium oxides, titanium oxides, tungsten oxides, etc. Consequently, only metals which have the highest affinity for oxygen, have chances to be successfully used as deoxidizing additions to self-fluxing brazing alloys.

Thus, the first and the most impor-

N. Bredzs and **D. Canonico** are associated with the Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill.

Presented at AWS National Spring Meeting held in Kansas City, Mo., June 7–10, 1955.

tant requirement for such deoxidizing metals is a high affinity for oxygen at the practical brazing temperature. Secondly, the products of the deoxidizing reactions, the oxides of the deoxidizing metal, should have comparatively low-melting points, or, at least, these oxides should form with the oxides of the base metal low-melting, fusible slags. Thirdly, for the manufacturing of the self-fluxing brazing alloys, at least a small solubility of the deoxidizing metal in the molten brazing alloy is absolutely necessary. Further, from the point of view of manufacturing, it is also quite important to have the deoxidizing metal with a possibly high boiling point. And finally, it is of a great advantage, if the additions of the deoxidizing metal reduce the surface tension of the molten brazing alloy, since this will promote the wetting of the solid base metal by the molten self-fluxing brazing alloy.

The metals comprising the group I-A in the periodic system of chemical elements, namely, the alkali metals Li, Na, K, Rb and Cs have the following properties:

1. Comparatively high affinity for oxygen.
2. Comparatively low-melting points of the oxides of these metals, and
3. The oxides of these metals form with most of the oxides of the other metals low-melting fusible slabs.

Accordingly, the alkali metals appear to be the most suitable metals for compounding self-fluxing brazing alloys.

Table 1 presents some chemical and physical properties of the alkali metals together with the properties of some other metals representing a selection of the strongest deoxidizers.

By comparing the properties of all of these metals, it is quite obvious that some of the strongest deoxidizers, Be, Mg, Al, Ca, Ti and Ba, definitely have a much higher affinity for oxygen than the alkali metals Cs, Rb, K and Na. Lithium, however, has about the same affinity for oxygen as the other strong deoxidizers. In Table 1 the oxygen affinity is expressed by free energy (and also heat) of the oxidation reaction of the pertinent metal at room temperature, 298° K(25° C), as well as at 1000° K(727° C).

Unfortunately, it is not feasible to compare the free energies of the oxidation of lithium with the free energies of the oxidation reaction of the other metals at practical brazing temperatures (800° F and above), since the free energy of the $2\,Li + {}^1/_2\,O_2 \rightarrow Li_2O$ reaction is determined only for room temperature. However, an approximate extrapolation—assuming that the rate of the decrease of the free energy with increasing temperature is about the same for lithium as it is for the metals sodium and potassium—shows that the free energy of the oxidation reaction for lithium at 1000° K(1340° F) should be in the order of magnitude of 100 to 115 K-cal.

By comparing the melting points of the oxides of the metals shown in Table 1, it is evident that the melting points of the oxides of the strongly deoxidizing metals are considerably higher than the melting points of the oxides of the alkali metals. As a matter of fact, the oxides of Be, Mg, Al, Ca, Ti and Ba are highly refractory. By brazing a certain base metal with a self-fluxing brazing alloy containing one of these elements, the base metal oxides on the base metal-filler metal interface will be reduced quite rapidly. However, as a result of such reaction, the base metal oxides on the base metal-filler metal interface will be replaced by a highly refractory oxide of the reducing element. For instance, by using a self-fluxing brazing alloy containing Mg for brazing of steel, which in a neutral or slightly oxidizing atmosphere normally is covered by a thin layer of iron oxides, the iron oxides will be reduced and replaced by a layer of MgO which certainly is more detrimental for obtaining sound brazed joints than are the iron oxides. That explains why the metals which form highly refractory oxides cannot be used as additions to self-fluxing brazing alloys.

By comparing the properties of the alkali metals, it is quite obvious that only lithium has a high enough affinity for oxygen to be able to reduce most of the metallic oxides. Furthermore, of all of the alkali metals only lithium has a high enough boiling point for effective manufacturing of self-fluxing brazing alloys. Only one property of lithium is not quite favorable for composing self-fluxing brazing alloys, namely, the melting point of lithium oxide is quite high, about 1700° C. However, since lithium oxide forms low-melting slags with most of the metallic oxides, it is quite obvious that lithium is almost an ideal metal for making self-fluxing brazing alloys.

In order to prepare lithium-bearing self-fluxing brazing alloys, lithium has to be dissolved in these alloys. A study of the binary phase diagrams reveals that lithium can be easily dissolved in two of the most important metals used for brazing alloys, namely, in silver (see Fig. 1*a*) and copper (see Fig. 1*b*).

Consequently, it was decided to start a systematic study of the self-fluxing lithium bearing brazing alloys with the investigation of the silver-lithium and silver-copper alloys.

Before going over to the experimental part of this work, it should be mentioned that an early attempt to apply lithium in brazing alloys was reported by Hensel, Larsen and Swazy.[6] These authors added small amounts of lithium, not exceeding 0.26%, to the BAg-9 silver base brazing alloy. The results of

Table I—Some Physical and Chemical Properties of the Alkali Metals and Some Other Strongly Deoxidizing Metals

Metal	*Melting point* ° *C*	*Boiling point,* ° *C*	*Oxidation reaction*	*Heat of the oxidation reaction* $-\Delta H°$ *298* K-cal	*Free energy of the oxidation reaction* $-\Delta F°$ *298* K-cal	$-\Delta F°$ *1000* K-cal	*Melting point of the oxide,* ° *C*	*References*
Li	186°	1336°	$2Li(c) + {}^1/_2O_2(g) \rightarrow Li_2O(c)$	142.6	134.0	...	>1700°	2, 3, 4, 5
Na	97.8°	883°	$2Na(c) + {}^1/_2O_2(g) \rightarrow Na_2O(c)$	100.7	91.4	...	1275°	2, 3, 4
			$2Na(l) + {}^1/_2O_2(g) \rightarrow Na_2O(c)$	...	...	67.5	subl.	3, 5
K	63.7°	760°	$2K(c) \pm {}^1/_2O_2(g) \rightarrow K_2O(c)$	86.1	76.7	...	...	2, 4
			$2K(l) + {}^1/_2O_2(g) \rightarrow K_2O(c)$	...	...	61.2	...	3, 5
Rb	39.0°	688°	$2Rb(c) + {}^1/_2O_2(g) \rightarrow Rb_2O(c)$	82.9	...	...	45°	2, 3, 4
Cs	28.5°	705°	$2Cs(c) + {}^1/_2O_2(g) \rightarrow Cs_2O(c)$	75.9	...	...	300–400° dec	2, 3, 4
Be	1278°	2970°	$Be(c) + {}^1/_2O_2(g) \rightarrow BeO(c)$	147.3	140.5	124.6	2530°	2, 4, 5
Mg	651°	1103°	$Mg(c) + {}^1/_2O_2(g) \rightarrow MgO(c)$	143.8	136.3	...	2800°	3, 4, 5
			$Mg(l) + {}^1/_2O_2(g) \rightarrow MgO(c)$	...	...	119.1	...	3, 5
Al	660.2°	2450°	${}^2/_3Al(c) + {}^1/_2O_2(g) \rightarrow {}^1/_3Al_2O_3(c)$	133.0	125.6	...	2050°	3, 4, 5
			${}^2/_3Al(l) + {}^1/_2O_2(g) \rightarrow {}^1/_3Al_2O_3(c)$	...	...	106.1	...	3, 5
Ca	850°	1440°	$Ca(c) + {}^1/_2O_2(g) \rightarrow CaO(c)$	151.7	144.3	127.7	2580°	2, 3, 4, 5
Ti	1690°	3535°	$Ti(c) + {}^1/_2O_2(g) \rightarrow TiO(c)$	135.0	128.0	102.5	1750°	2, 3, 4, 5
Ba	710°	1500°	$Ba(c) + {}^1/_2O_2(g) \rightarrow BaO(c)$	133.1	119.0	102.7	1923°	2, 3, 4, 5

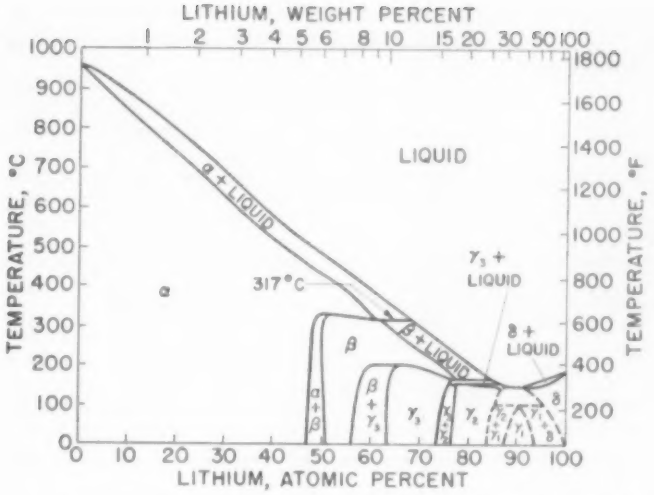


Fig. 1*a* Equilibrium diagram of silver-lithium system (according to W. E. Freeth and G. V. Raynor[7]

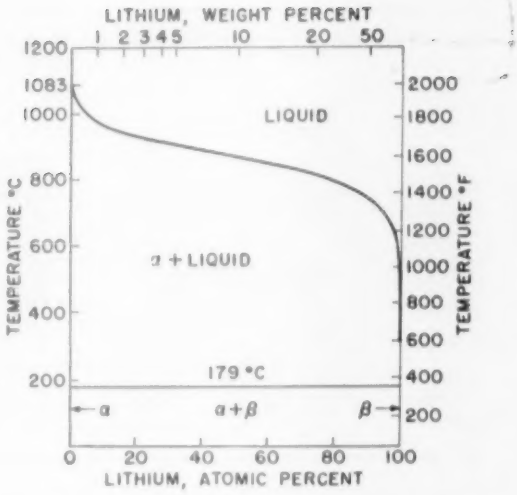


Fig. 1*b* Equilibrium diagram of copper-lithium system[8]

their experiments are summarized as follows: "A comparison of the new lithium bearing silver solder with some of the standard silver solders indicates that, particularly on large brazed sections, this new material is superior as far as fluidity, wetting and resulting tensile and cross-breaking strength properties are concerned. The superiority was shown not only in the brazing of copper to tungsten copper, but also in the brazing of certain ferrous and nonferrous materials. The new brazing alloy is particularly useful in the brazing of nickel or ferrous alloys containing oxidizable ingredients, such as chromium, molybdenum and tungsten."

However, the lithium bearing alloys made by these authors were used exclusively for brazing under fluxes. They do not mention any brazing experiments which were done without fluxes. Since the purpose of the present work was to investigate the self-fluxing properties of lithium bearing brazing alloys, the work of Hensel, Larsen and Swazy does not directly interfere with our investigation.

Investigation of the Silver-Lithium Alloys

A. Wettability Tests

In order to prove the superiority of the lithium bearing silver alloys as self-fluxing brazing alloys, it was decided to begin with an investigation of the wetting of slightly oxidized SAE 1020 steel surfaces by molten silver with 1% addition of the following deoxidizing elements: Be, Mg, Al, Si, Ca, Ni, Cu, Zn, Cd, Sn, Ba and Li.

The scope of this investigation was:

1. To study the wetting of low-carbon steel by molten silver with 1% addition of various deoxidizing elements.
2. To study the ability of the deoxidizing elements to reduce the iron oxide layers on the slightly oxidized surface of low-carbon steel.

In order to exclude any disturbing or complication influences which might be caused by using alloy or high-carbon steels for the wettability tests, these studies were begun with low-carbon steel. Later the work could be extended to more complicated cases, namely, wettability of high-carbon steels and alloy steels.

In order to exclude heavy oxidation of the steel surfaces and also the oxidation of the deoxidizing elements on the molten silver surface during the heating period and the subsequent spreading period, the wettability tests were carried out in a helium atmosphere. Since it is not feasible to obtain an absolute dry helium atmosphere, a slight oxidation of the steel surfaces during the heating period would take place. The resulting thin film of iron oxides on the steel surface would create almost ideal conditions for testing the deoxidizing abilities of the various additions to molten silver at practical brazing temperatures.

Preparation of the alloys. The silver alloys for the wettability tests were prepared by melting 99 wt % (35 g) of pure silver with 1 wt % (0.35 g) of the pertinent deoxidizing metal. The melting of those alloys was performed in porcelain crucibles under 10% H_2 + 90% N_2 atmosphere.

The 1% Li alloy was melted under dry helium atmosphere. The 1% Cu and 1% Zn alloys were prepared from master alloys (commercial brazing alloys BAg-8 and 75% Ag, 25% Zn, respectively) by adding the necessary amount of pure silver.

The chemical analysis of these silver alloys yielded the following results:

Alloys	*Analysis*
Al–Ag	1.09% Al balance Ag
Ba–Ag	0.56% Ba balance Ag
Be–Ag	0.91% Be balance Ag
Ca–Ag	0.89% Ca balance Ag
Cd–Ag	0.87% Cd balance Ag
Cu–Ag	1.16% Cu balance Ag
Li–Ag	0.37% Li balance Ag
Mg–Ag	0.83% Mg balance Ag
Ni–Ag	1.23% Ni balance Ag
Si–Ag	1.02% Si balance Ag
Sn–Ag	0.75% Sn balance Ag
Zn–Ag	0.98% Zn balance Ag

As the results of the chemical analysis show, only in the case of the Ag–Li alloy was the percentage of the deoxidizing ingredient considerably below 1%, presumably due to the lithium losses during the remelting of the alloy in helium which was not absolutely dry. The content of all other deoxidizing elements was roughly 1%.

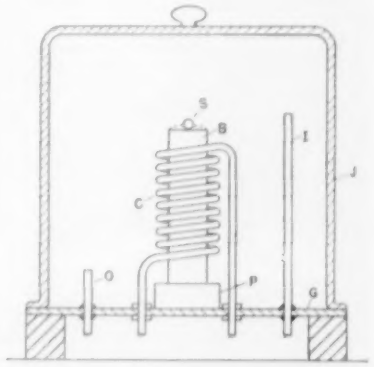


Fig. 2 Experimental apparatus for wettability tests

B—Cylindrical low-carbon steel bar; C—water-cooled induction coil; G—glass plate; I—gas inlet tube; J—glass jar; O—gas outlet tube; P—transite block; S—filler metal nodule (dotted line indicates the shape of the filler metal drop after melting).

Table 2—Results of Wettability Tests with Various Silver Alloys on Polished Low-Carbon Steel Surfaces Under Dry Helium Atmospheres

Sample No.	*Composition of silver alloy*	*Temperature of silver alloy*	*Base metal*	*Atmosphere*	*Diameter of drop, in.*
247	1% Ca, bal. Ag	Slightly over the mp of the silver alloy	Low-carbon steel	Dry helium	0.20
258	1% Mg, bal. Ag	Slightly over the mp of the silver alloy	Low-carbon steel	Dry helium	0.25
253	1% Al, bal. Ag	Slightly over the mp of the silver alloy	Low-carbon steel	Dry helium	0.33
254	1% Be, bal. Ag	Slightly over the mp of the silver alloy	Low-carbon steel	Dry helium	0.40
252	1% Si, bal. Ag	Slightly over the mp of the silver alloy	Low-carbon steel	Dry helium	0.40
248	1% Ni, bal. Ag	Slightly over the mp of the silver alloy	Low-carbon steel	Dry helium	0.40
250	pure Ag	Slightly over the mp of pure silver	Low-carbon steel	Dry helium	0.40
251	pure Ag	Slightly over the mp of pure silver	Low-carbon steel	10% H_2 + 90% N_2	0.40
246	1% Sn, bal. Ag	Slightly over the mp of the silver alloy	Low-carbon steel	Dry helium	0.40
256	1% Zn, bal. Ag	Slightly over the mp of the silver alloy	Low-carbon steel	Dry helium	0.40
259	1% Cu, bal. Ag	Slightly over the mp of the silver alloy	Low-carbon steel	Dry helium	0.40
255	1% Cd, bal. Ag	Slightly over the mp of the silver alloy	Low-carbon steel	Dry helium	0.40
249	1% Ba, bal. Ag	Slightly over the mp of the silver alloy	Low-carbon steel	Dry helium	0.65
257	1% Li, bal. Ag	Slightly over the mp of the silver alloy	Low-carbon steel	Dry helium	0.75

Experimental Apparatus and Methods. The apparatus used for the wettability tests is illustrated in Fig. 2. For the wettability tests 3/4 in. diameter cylindrical low-carbon steel bars 3 in. long were used. The end surfaces of these bars were ground and polished. Each of the steel bars, *B*, with a polished top surface was placed vertically in the induction coil, *C*, as shown in Fig. 2. A small nodule was placed precisely on the center of the polished upper surface of the bar, *B*. The weight of each nodule was exactly 1 g.

After placing the silver alloy nodule on the center of the top surface of the steel bar, *B*, the apparatus was covered by the glass jar, *J*, and a slow flow of helium gas was turned on for 10–15 minutes. After the last traces of oxygen were removed and the air was completely replaced by helium, the high frequency current was introduced. Shortly before the silver alloy melted on the surface of the bar, *B*, the characteristic blue color, signifying slight oxidation, appeared on the steel surface. Then the silver nodule melted and, with a few exceptions which will be discussed in more detail later, rapidly spread over the polished end surfaces of the bars.

Just after the molten silver alloy drop was formed on the end surface of the bar, the power was turned off, the bar cooled down to room temperature, and the diameter of the solidified drop measured.

The average diameter values for the various silver alloys are summarized in Table 2.

After the spreading diameter measurements were completed, the ends of the bars with the solidified silver alloy disks on top were cut off and cross sectioned through the longitudinal axis of the bars. Figure 3 shows an enlarged photograph of the ground and polished surfaces of these cross sections. Figures 4 to 13 show the steel-silver alloy interfaces of these samples under a larger magnification (× 150).

Discussion of the Wetting Experiments. In Fig. 3 the top row of the samples, from left to right, presents 1% Ca — 99% Ag alloy, 1% Mg — 99% Ag alloy, and 1% Al — 99% Ag alloy (Figs. 3*a*, 3*b* and 3*c*). As the photograph shows, these three alloys produced very weak wetting, as a matter of fact, much poorer than the wettability of pure silver without any deoxidizing additions (compare samples 247, 258 and 253 with sample 250 in Table 2, also Figs. 3*a*, 3*b*

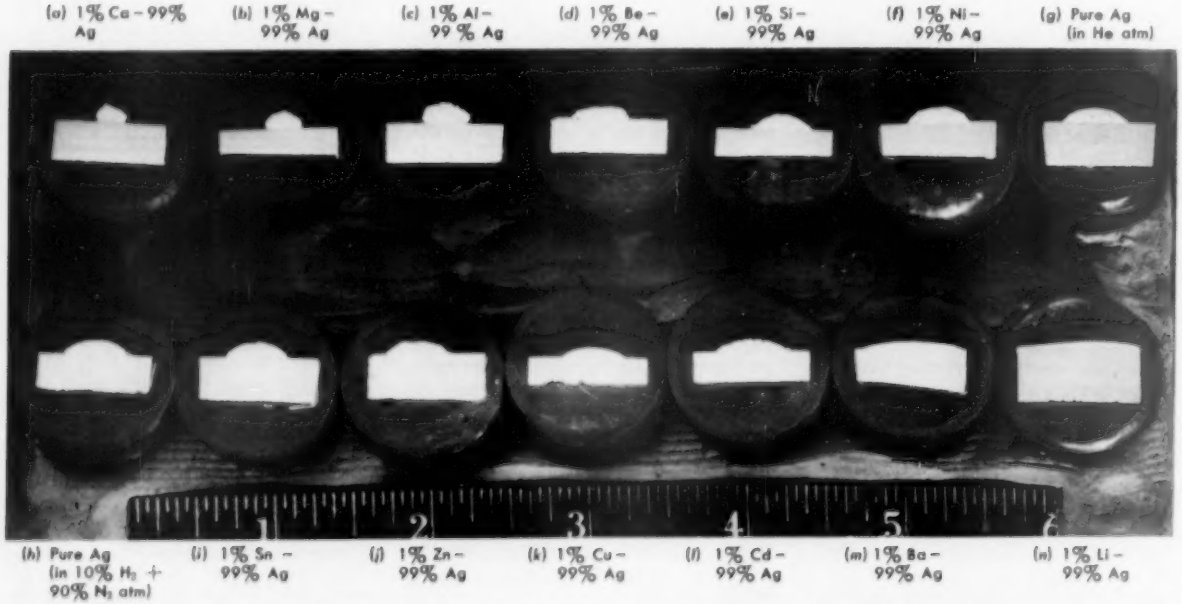

(a) 1% Ca – 99% Ag
(b) 1% Mg – 99% Ag
(c) 1% Al – 99% Ag
(d) 1% Be – 99% Ag
(e) 1% Si – 99% Ag
(f) 1% Ni – 99% Ag
(g) Pure Ag (in He atm)
(h) Pure Ag (in 10% H2 + 90% N2 atm)
(i) 1% Sn – 99% Ag
(j) 1% Zn – 99% Ag
(k) 1% Cu – 99% Ag
(l) 1% Cd – 99% Ag
(m) 1% Ba – 99% Ag
(n) 1% Li – 99% Ag

Fig. 3 Cross sections through solidified silver alloy drops, made after spreading tests on polished end surfaces of low-carbon steel bars under dry helium atmosphere

and 3*c* with Fig. 3*g*).

During the melting of these alloys on top of the steel bars, it has been observed that as soon as the alloys started to melt a thin white film of oxides appeared on the molten surface. Apparently the metals Ca, Mg and Al, which have a high affinity for oxygen, pick up the last traces of moisture from the helium gas and form a thin oxide film on the liquid silver alloy surface. Since the oxides of these metals are highly refractory, the molten silver alloy cannot break through the oxide film and spread over the steel surface. Only after a longer heating time did the molten silver alloy sometimes break the oxide film and spread over the steel surface; even then, however, the spreading diameter of the drop was always below the spreading diameter of pure silver.

One might anticipate that the metals which have a great affinity for oxygen, such as Ca, Mg and Al, would readily reduce the iron oxides on the steel surface and thus increase the wettability of the silver alloys. The spreading tests, however, show that such reactions result only in replacement of the iron oxide layers on the steel surface by layers of highly refractory oxides, CaO, MgO and Al_2O_3, which offer even more interference with efficient wetting than the original iron oxide layers. An examination of the steel-silver alloy interfaces under a larger magnification (× 150) fully confirmed this observation. On these photomicrographs (Figs. 4, 5 and 6) the steel surface is separated from the silver drop by a large gap partly filled with refractory oxides (Fig. 4 shows the photomicrographs of the steel—1% Ca – 99% Ag alloy interface: Fig. 5 shows the steel—1% Mg – 99% Ag alloy interface: and Fig. 6 shows the steel—1% Al – 99% Ag alloy interface, respectively).

The next, 1% Be – 99% Ag alloy, presents a very similar picture (sample 254, Table 2, Fig. 3*d* and Fig. 7). Here, also, the refractory character of the beryllium oxide seems to prevent sufficient wetting. In the case of the 1% Si – 99% Ag alloy (sample 252, Table 2, Figs. 3*e* and 8) the wettability picture may be complicated by the formation of intermetallic compound layers (presumably solid solutions of FeSi or Fe_3Si_2 in iron). This assumption is confirmed by the photomicrographs of Fig. 8, which quite effectively show the formation of intermetallic compound layers on the steel-silver alloy interface. In general, however, as before, the addition of 1% of a strongly deoxidizing metal (Si) has not increased the wettability of steel by molten silver. The next five alloys—the 1% Ni – 99% Ag alloy (sample 248, Table 2, Figs. 3*f* and 9), the 1% Sn – 99% Ag alloy (sample 246, Table 2, Fig. 3*i*), the 1% Zn – 99% Ag alloy (sample 256, Table 2, Fig. 3*j*), the 1% Cu – 99% Ag alloy (sample 259, Table 2, Fig. 3*k*), and the 1% Cd – 99% Ag alloy (sample 255, Table 2, Fig. 3*l*)—all show the same pattern, namely, the 1% addition of the deoxidizing elements Ni, Sn, Zn, Cu and Cd does not change the wetting properties of molten silver. Apparently these

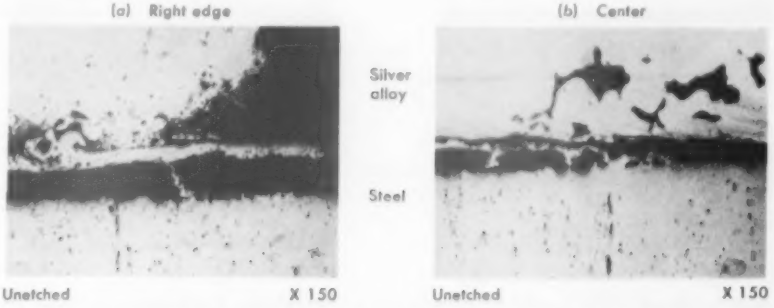


Fig. 4 Steel—1% Ca – 99% Ag alloy interface shown in Fig. 3*a* (reduced by 1/3 upon reproduction)

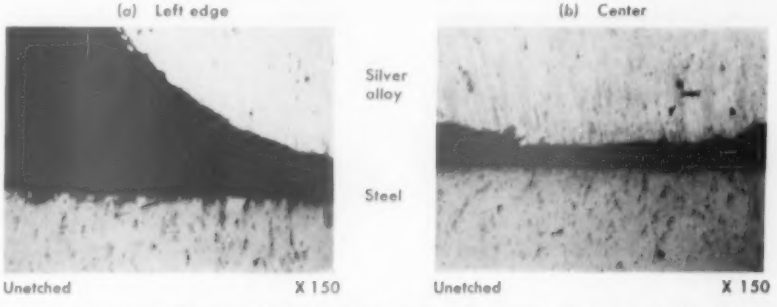


Fig. 5 Steel—1% Mg – 99% Ag alloy interface shown in Fig. 3*b* (reduced by 1/3 upon reproduction)

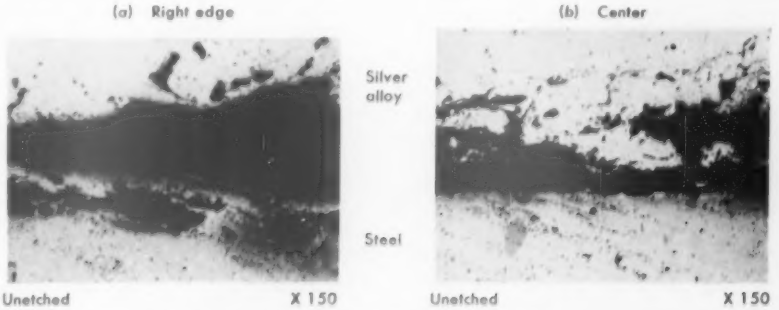


Fig. 6 Steel—1% Al – 99% Ag alloy interface shown on Fig. 3*c* (reduced by 1/3 upon reproduction)

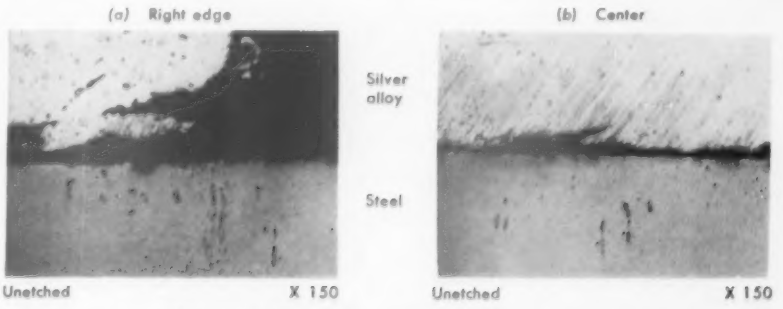


Fig. 7 Steel—1% Be – 99% Ag alloy interface shown in Fig. 3*d* (reduced by 1/3 upon reproduction)

metals are too weak deoxiders for reducing of iron oxides under the given conditions.

A completely different pattern is shown by the 1% Ba – 99% Ag alloy (sample 249, Table 2, Figs. 3*m* and 12).

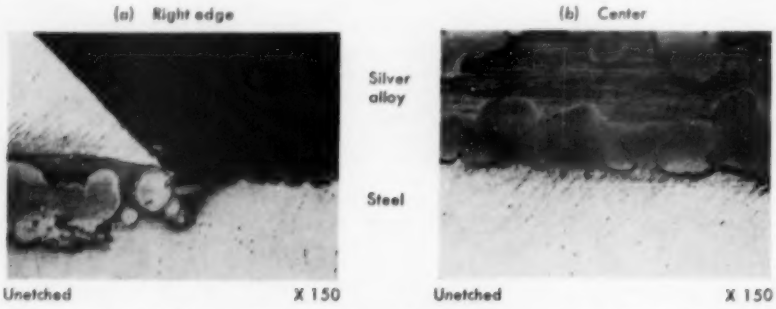


Fig. 8 Steel—1% Si – 99% Ag alloy interface shown in Fig. 3e (reduced by 1/3 upon reproduction)

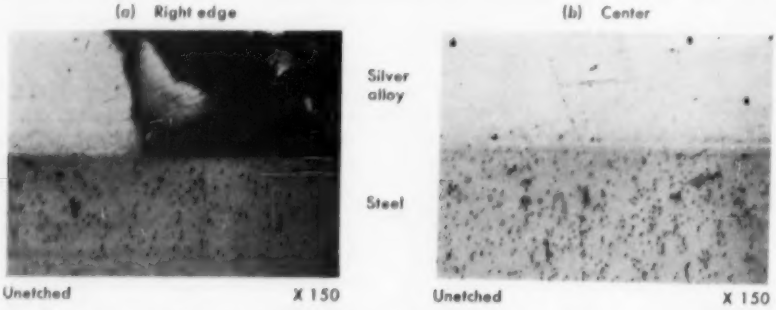


Fig. 9 Steel—1% Ni – 99% Ag alloy interface shown in Fig. 3f (reduced by 1/3 upon reproduction)

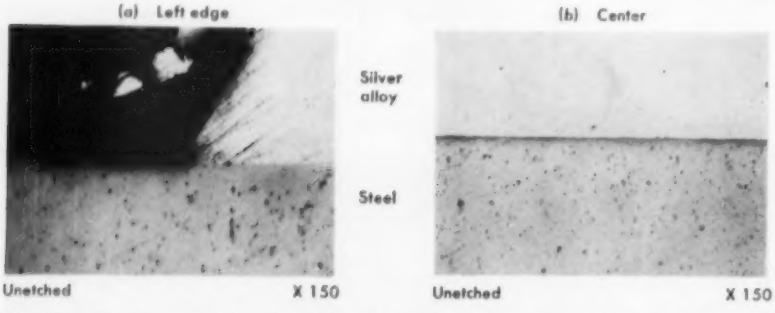


Fig. 10 Steel—pure silver interface under dry helium atmosphere (see Fig. 3g) (reduced by 1/3 upon reproduction)

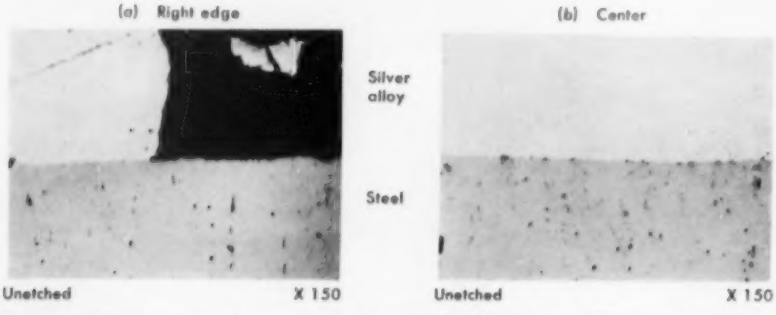


Fig. 11 Steel—pure silver interface under 10% H_2 + 90% N_2 atmosphere (see Fig. 3h) (reduced by 1/3 upon reproduction)

An addition of 1% Ba results in an appreciable increase of the spreading diameter, most likely due to the high affinity of barium for oxygen and the comparatively low-melting point of the products of the deoxidizing reaction: barium oxide (m.p. 1923° C), and the barium oxide-iron oxide slag.

The most effective deoxidizing alloy, however, is the 1% Li – 99% Ag alloy (sample 257, Table 2, Figs. 3*n* and 13). The molten 1% Li, 99% Ag alloy not only spread over the entire end surface of the steel bars but even flowed over the edges and wetted the upper part of the side surface of the cylindrical bars. The high affinity of lithium for oxygen and the low-melting point of Li_2O, or, more correctly, the low-melting point of Li_2O-FeO slag apparently are responsible for the high deoxidizing and wetting ability of this alloy.

For the sake of better surveilance of the wettability tests, in Fig. 3 are also shown the cross sections of pure silver drops obtained by melting in dry helium atmosphere (Fig. 3*g*) and in 10% H_2 + 90% N_2 atmosphere (Fig. 3*h*). Figures 10 and 11 show the photomicrographs of the steel-pure silver interfaces on the polished cross sections of these samples under a larger magnification (× 150).

B. Wetting of Drill Rod and 303 Stainless Steel by 1% Li–99% Ag Alloy

Experimental Results. All twelve silver alloys with 1% additions of various deoxidizing elements (the chemical analysis of these alloys is presented in the Section II A) have also been tested for wettability of slightly oxidized drill rod steel (1% C) surfaces and 303 stainless steel surfaces. From all of the twelve silver alloys investigated, only the 1% Li – 99% Ag alloy showed the same high wettability on drill rod and stainless steel surfaces as on low-carbon steel surfaces. The 1% Ba – 99% Ag alloy yielded quite good wettability on carbon steel surfaces, but quite poor wettability on 303 stainless steel surfaces.

For these tests the same experimental techniques and the same experimental apparatus have been used as for the investigation of low-carbon steel. The techniques are reported and the apparatus described in the previous section (see Fig. 2). All the wettability tests have been performed in helium atmosphere.

Figure 14 shows an enlarged photograph of the slightly oxidized end surfaces of the steel bars with pure silver drops and the 1% Li – 99% Ag alloy pellets on top of them. The photograph was taken immediately after solidification of the silver drops. In Fig. 14 the top row of samples, from left to right, presents pure silver on low-carbon steel, drill rod, and 303 stainless steel (Figs. 14*a*, 14*b* and 14*c*). The

bottom row shows the wetting of the same steel samples by 1% Li – 99% Ag alloy (Figs. 14*d*, 14*e* and 14*f*).

After the spreading tests were completed and the photograph was taken, the end surfaces of the bars with the solidified silver and silver alloy drops on their tops were cut off and cross sectioned through the longitudinal axis of the bars (see Fig. 15).

Figures 16 to 18 show the steel-silver interfaces of the samples shown in Figs. 15*a*, 15*b* and 15*c*, under a larger magnification (× 150). Figures 19 to 21 show the corresponding steel—1% Li, 99% Ag interfaces under the same magnification (× 150).

As these photomicrographs show, the addition of 1% Li to silver results in complete reduction of the iron oxides on the steel-silver interface and in an excellent wetting of the deoxidized steel surfaces.

Summary of the Wetting Experiments. The experimental results obtained on investigation of the wettability of low carbon steel, drill rod, and 303 stainless steel by molten 1% Li – 99% Ag alloy indicate that small additions of lithium to pure silver considerably decrease the contact angle of the molten silver on carbon steel surfaces, as well as on alloy steel surfaces.

The lowering of the contact angle shows in Fig. 15. By comparing the cross sections shown in Figs. 15*a*, 15*b* and 15*c* with the ones shown in Fig. 15*d*, 15*e* and 15*f*, it is quite obvious that even a small addition of lithium decreases the wetting angle almost to zero (see also Figs. 20 and 21).

The molten 1% Li, 99% Al alloy not only spread over the entire surface of the steel bars, but even flowed over the edges and wetted the upper part of the side surface of the cylindrical surface of the bars. That indicates that the wetting and self-fluxing properties of this alloy on slightly oxidized steel are extremely high.

In order to investigate the practical applicability of the lithium bearing silver alloys in brazing of various carbon steels and stainless steels, it was decided to prepare larger quantities of: (1) 1% Li, 99% Ag alloy, (2) 2% Li, 98% Ag alloy and (3) 1% Li, 28% Cu, 71% Ag alloy.

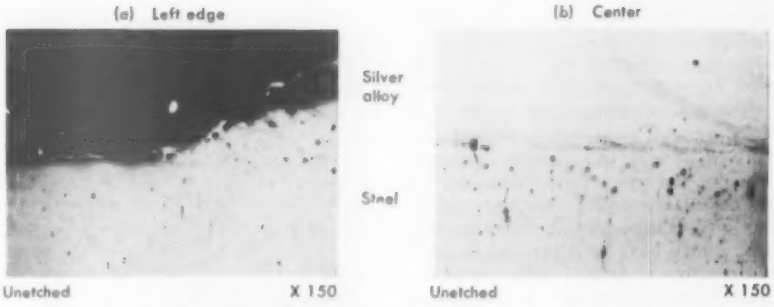


Fig. 12 Steel—1% Ba – 99% Ag alloy interface shown in Fig. 3*m* (reduced by 1/2 upon reproduction)

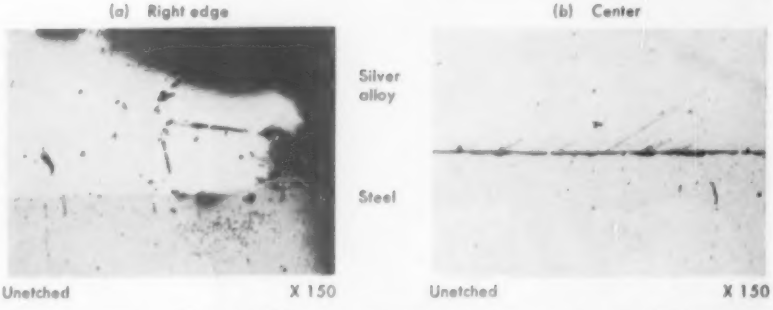


Fig. 13 Steel—1% Li – 99% Ag alloy interface shown in Fig. 3*n* (reduced by 1/2 upon reproduction)

Furthermore, it was decided to try to prepare from these alloys cold rolled sheets and strips, and to investigate the corrosion resistance of these strips in air and in water. Further, it was decided to apply these alloys for brazing of various steels in an inert atmosphere and to determine the tensile strength of the joints brazed with these alloys.

The techniques of preparation of these alloys and the pertinent brazing experiments are reported in the following section.

C. Brazing Experiments with Lithium-Silver Alloys

The 1% Li – 99% Ag alloy and the 2% Li – 98% Ag alloy were prepared by melting 50 grams of degassified pure silver with the desired amount of lithium in recrystallized alumina crucibles. The degassification of the silver was accomplished by remelting the commercial (not completely oxygen free) silver in 10% H_2 + 90% N_2 atmosphere. During the degassification experiments, it was seen that upon remelting the "degassified" silver in 10% H_2 + 90% N_2 atmosphere gas evolution again oc-

Table 3—Tensile Test Results of 303 Stainless Steel Bars Brazed with 1% Li – 99% Ag and 2% Li – 98% Ag Brazing Alloys Under 10% H_2 + 90% N_2 and Pure Nitrogen Atmosphere (After Brazing, the Brazed Bars Were Cooled in Air)

Specimen Number (% Li in parentheses)	*Bar diam, in.*	*Joint thickness, in.*					*Fracture load, lb*	*Ultimate tensile strength, psi*	*Quality of the metallic bond*	*Protective gas*
		0°	*90°*	*180°*	*270°*	*Average*				
LAS 263 (1% Li)	0.5038	0.0051	0.0055	0.0058	0.0051	0.0054	9750	48,900	Absolutely sound and voidless	N_2
LAS 264 (1% Li)	0.4916	0.0056	0.0060	0.0053	0.0050	0.0055	9880	52,100	Absolutely sound and voidless	N_2
LAS 265 (1% Li)	0.4974	0.0053	0.0063	0.0056	0.0060	0.0058	8650	44,500	Absolutely sound and voidless	10% H_2 + 90% N_2
LAS 266 (1% Li)	0.5060	0.0066	0.0067	0.0065	0.0064	0.0065	8100	40,300	Absolutely sound and voidless	10% H_2 + 90% N_2
LAS 271 (1% Li)	0.5000	0.000308	0.000376	0.000011	0.000044	0.000185	8950	45,600	Absolutely sound and voidless	N_2
LAS 272 (2% Li)	0.5066	0.000359	0.000329	0.000011	0.000051	0.000136	9800	48,600	Some nonmetallic inclusions	N_2

curred. The evolution of gas from molten silver ceased completely only after four remelting operations in the 10% H_2 + 90% N_2 atmosphere.

The proper amount of freshly cut lithium metal pieces was placed on the bottom of the recrystallized alumina crucible, and covered by 50 grams of the degassified silver. In order to minimize the amount of moisture in the protective gas, the melting of silver was done in vacuum (4 in.) after purging the glass jar for 15 minutes with dry helium gas.

The same melting procedure was applied for preparation of the 1% Li – 28% Cu – 71% Ag alloy, except that instead of 50 grams of pure silver the same amount of commercial BAg-8 brazing alloy was used for preparation of this alloy.

All three of the alloys were cold rolled to thin sheet (0.063 in.). In order to make these sheets applicable for brazing of steel specimen, they were cut to thin strips. The 1% Li – 99% Ag and 1% Li – 28% Cu – 71% Ag alloy strips did not show any signs of corrosion or decrease of self-fluxing properties even after standing in the air for one week, and after dipping in water for 24 hours.

The 2% Li – 98% Ag alloy was not quite as corrosion resistant as the two previous alloys, and not as ductile. In the fractured brazed joints this alloy produced some signs of nonmetallic inclusions (presumably Li_2O, LiOH and Li_2O-FeO). However, the maximum tensile strength (48,600 psi) of the joints brazed with this alloy was almost the same as the maximum tensile strength of the 1% Li – 99% Ag joints (52,100 psi).

In order to determine the tensile strength of the joints brazed with 1% Li – 99% Ag and 2% Li – 98% Ag alloys, a series of slightly oxidized 3 in. long, 3/4 in. diameter 303 stainless steel bars was brazed with these alloys. These bars were brazed by induction heating. Some of the bars were brazed in 10% H_2 + 90% N_2 atmosphere, the rest in dry nitrogen atmosphere. After brazing, the bars were turned down to standards 0.505 in. diameter tensile test specimens. The results of the tensile tests are summarized in Table 3.

Some 303 stainless steel strips torch brazed in oxy-acetylene atmosphere with 1% Li – 99% Ag alloy yielded quite sound, strong joints.

D. Brazing Experiments with 1% Li – 99% Cu Alloy

The 1% Li – 99% Cu alloy was prepared by melting 50 grams of deoxidized, pure copper with 0.5 grams of lithium in recrystallized alumina crucibles.

Some slightly oxidized 303 stainless steel bars have been brazed with 1%

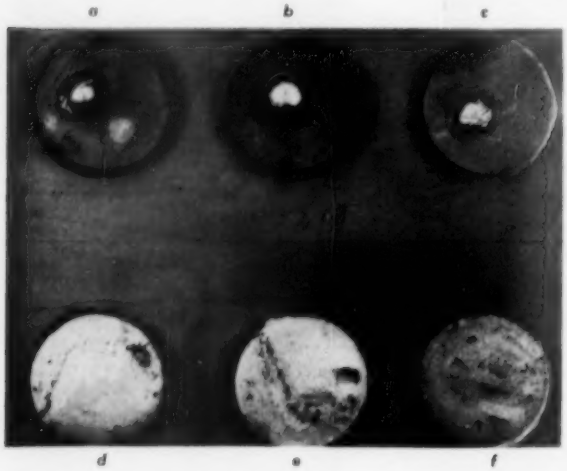


Fig. 14 Photograph of the end surfaces of steel bars with molten silver and molten 1% Li – 99% Ag alloy drops on top

(a) Pure silver on low-carbon steel (0.20% C). (b) Pure silver on drill rod (1.00% C). (c) Pure silver on 303 stainless steel. (d) 1% Li – 99% Ag on low-carbon steel (0.20% C). (e) 1% Li – 99% Ag on drill rod (1.00% C). (f) 1% Li – 99% Ag on 303 stainless steel.

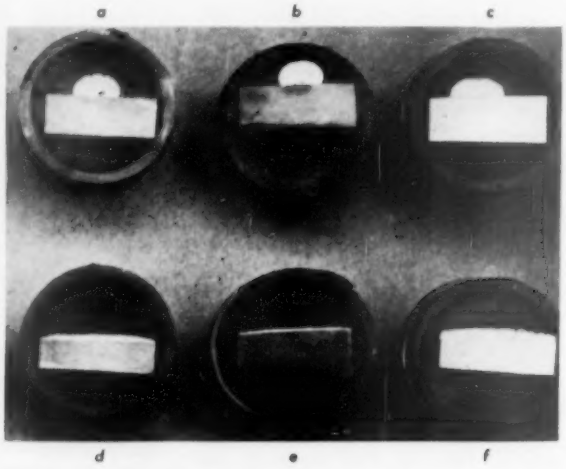


Fig. 15 Cross sections through the end surfaces of the steel bars shown in Fig. 14

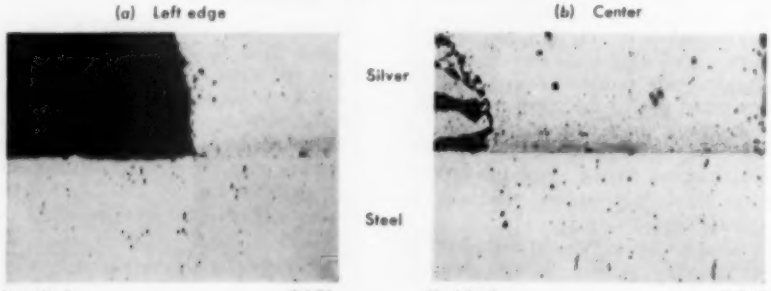


Fig. 16 Low-carbon steel—pure silver interface in dry helium atmosphere, shown in Fig. 15a (reduced by 1/3 upon reproduction)

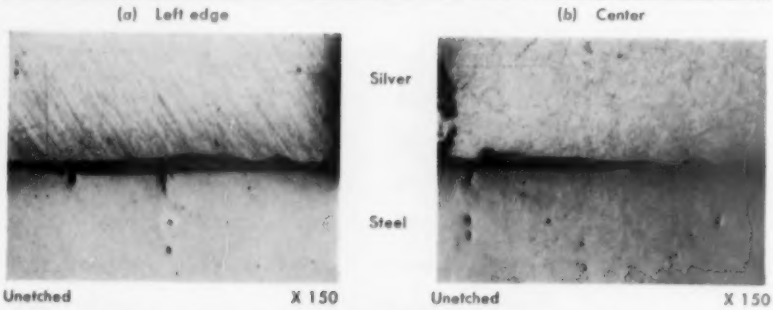


Fig. 17 Drill rod—pure silver interface in dry helium atmosphere, shown in Fig. 15b (reduced by 1/3 upon reproduction)

Li – 99% Cu alloy under nitrogen atmosphere. The maximum tensile strength of the bars brazed with this alloy was 39,500 psi, on a 0.00012 in. thick joint.

Some 303 stainless steel strips torch brazed in oxy-acetylene atmosphere with 1% Li – 99% Cu alloy yielded quite sound strong joints.

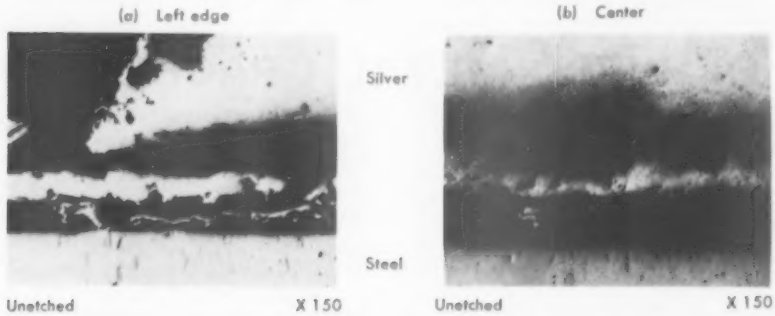


Fig. 18 303 stainless steel—pure silver interface in dry helium atmosphere, shown in in Fig. 15c (reduced by 1/2 upon reproduction)

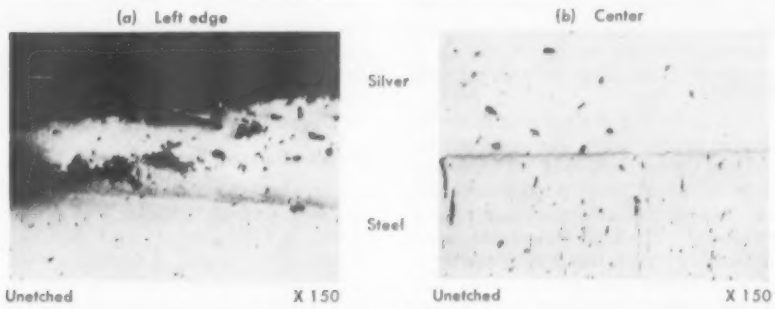


Fig. 19 Low-carbon steel—1% Li – 99% Ag alloy interface in dry helium atmosphere, shown in Fig. 15d (reduced by 1/2 upon reproduction)

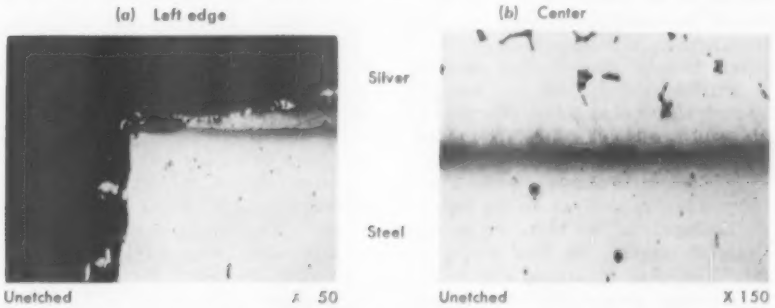


Fig. 20 Drill rod—1% Li – 99% Ag interface in dry helium atmosphere, shown in Fig. 15e (reduced by 1/2 upon reproduction)

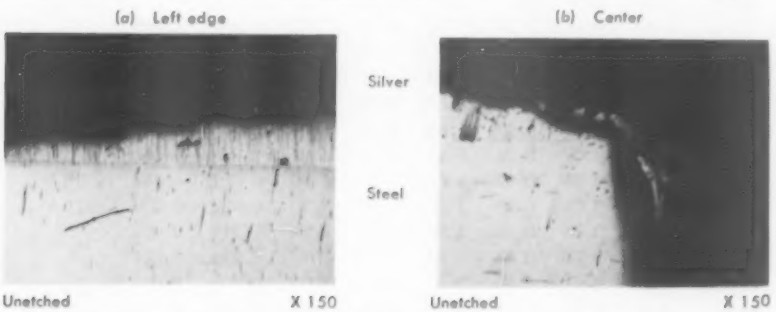


Fig. 21 303 stainless steel—1% Li – 99% Ag interface in dry helium atmosphere, shown in Fig. 15f (reduced by 1/2 upon reproduction)

Conclusions

In summary, the following conclusions are evident:

1. The experimental results obtained on investigation of wettability of low-carbon steel, drill rod, and 303 stainless steel with the molten 1% Li – 99% Ag alloy fully confirmed the theoretical postulation that lithium is a most suitable metal for developing self-fluxing brazing alloys. This theoretical postulation has been based on comparing some chemical and physical properties of lithium with some other strongly deoxidizing metals.

2. Small additions of lithium to silver result in self-fluxing brazing alloys which are capable of brazing carbon and alloy steels without either flux or reducing gases.

3. Small additions of lithium considerably lower the wetting contact angle of molten silver on carbon, as well as on stainless steel surfaces, thus promoting extremely good wettability and fluidity of the lithium bearing silver alloys.

4. Some preliminary brazing experiments performed in air indicate some new possibilities for developing self-fluxing, air proof brazing alloys.

Acknowledgments

The authors wish to express their appreciation to the Pitman Dunn Laboratory of the Frankford Arsenal for sponsoring this investigation at the Armour Research Foundation, for granting their permission to publish this work, and specifically to Frank W. Hussey for his technical assistance.

The authors also wish to express their appreciation to the Lithium Corporation of America for sponsoring an extended research program on the use of lithium in brazing alloys, and specifically to Walter M. Fenton.

In addition, the authors wish to acknowledge the assistance of Dr. William Rostoker and Orville T. Barnett, the past and present Supervisors of the Welding Section who were in charge of this study; Edmund Klimek, Supervisor of the Metallographic Services, and Edward R. Roeder, Senior Technician at the Armour Research Foundation.

Bibliography

1. Beal, F. W., "Stainless Brazed Without Fluxing," *Steel*, **130**, p. 57 (Jan. 14, 1952).
2. Rare Metals Handbook, by Clifford R. Hampel, Reinhold Publishing Co., 1954.
3. Liquid Metals Handbook, Atomic Energy Commission, Department of the Navy, 1952.
4. Handbook of Chemistry and Physics, 35th Edition, 1953–54.
5. Metallurgical Thermochemistry, by O. Kubaschewsky and E. L. Evans, London—New York, Academic Press Inc., 1951.
6. Hensel, F. R., Larson, E. L., and Swasy, E. W., "A Lithium Bearing Silver Solder," *Metals and Alloys*, 962–964 (June 1942).
7. Freeth, W. E., and Raynor, G. V., "The Constitution of the System Silver-Lithium," *Journal of the Institute of Metals*, **82**, 569 (1953–54).
8. S. Pastorello, Gazetta Chimica Italiana, **60**, 958 (1930).

INVESTIGATION OF WELD-METAL CRACKING IN HIGH-STRENGTH STEEL

Hot-cracking resistance of high-strength weld metals studied with relation to composition variables; increasing carbon, sulfur and phosphorus contents found to have adverse effects

BY R. P. SOPHER, A. J. JACOBS AND P. J. RIEPPEL

ABSTRACT. Special apparatus was developed to study the basic causes of cracking in high-strength weld metals. Hot-tension properties of selected high-strength weld metals were determined during cooling down from the molten state. The hot-cracking resistance of those same steels were studied with relation to composition variables. Particular emphasis was placed on a quantitative study of carbon, sulfur and phosphorus variations in SAE 43XX-type weld metals. The results indicate that increasing carbon, sulfur and phosphorus contents have adverse effects on hot-tension properties and hot-cracking resistance. Sulfur and phosphorus seem to be more detrimental than carbon. The promising possibility exists that high-carbon filler wires, low in residuals such as sulfur and phosphorus, can be deposited under conditions of high restraint. This weld metal then can be heat treated with the base plate to high-strength levels for commercial applications. A plausible explanation for hot cracking is suggested in terms of typical hot strength and ductility curves. This explanation receives support from the results of cracking tests. A limited amount of light microscope work was conducted on weld deposits and tested hot-tension specimens. A slight but definite association was shown to exist between the presence of intergranular eutectics in the tension specimens and poor hot ductility.

Introduction

Weld-metal cracking has caused much concern to the welding engineer and metallurgist. In the aircraft industry, the service requirements have made it essential that the welded assemblies in high-strength steels be free of defects.

Since weight is of great importance, the materials used in the weldments must be high quality. With the development of higher strength steels, it was apparent that information was needed to improve the quality of the weld metals used on these steels.

R. P. Sopher is Assistant Chief, Metals Joining Division, Battelle Memorial Institute, A. J. Jacobs, Research Associate, Ohio State University, formerly Research Engineer, Battelle Memorial Institute, and P. J. Rieppel is Chief, Metals Joining Division of Battelle Memorial Institute, Columbus, Ohio.

Presented at National Spring Meeting held in Kansas City, Mo., June 7-10, 1955.

In recognition of this situation, the Air Materiel Command sponsored this investigation to study the causes of weld-metal cracking in high-strength steels.

It was decided at the outset of the investigation to survey the pertinent literature dating from 1935. This survey covered about 1450 published papers on weld-metal cracking and related subjects.[1] The most important conclusions drawn from this survey and from a consultation with industry were that: (1) the major type of cracking in weld metals is hot cracking, which occurs at elevated temperatures; (2) most cracking in weld metals is intergranular and appears to be associated with segregation of low-melting or brittle constituents, as well as with stresses imposed during cooling; and (3) hot cracking in ferritic weld deposits is promoted by such elements as sulfur, phosphorus, oxygen, nickel (plus sulfur) and carbon, and reduced by manganese.

The experimental program was planned and carried out on the basis of the findings from the literature survey. Only hot cracking has been studied so far. The plan of attack was to try to correlate changes in high-temperature (1800 to 2700° F) tension properties with cracking susceptibility and to correlate these properties with composition. Attempts were made also to locate detrimental constituents in the weld deposits.

Preparation of Experimental Heats

Three basic compositions of steel were studied: SAE 43XX steel, a steel simulating a high-strength weld metal of the E15016 class, and a boron steel simulating AISI 86B40. The compositions of these heats are shown in Table 1.

Heats 1 through 6, 11, 12 and 1-H are SAE 43XX-type steels. Heats 1 through 6, 11 and 12 are induction heats, while 1-H is a basic electric heat. All heats except 4 and 12 were made with electrolytic iron and other high-purity materials. The latter two heats were made with normal scrap and ferroalloy additions throughout. Melting was done in an MgO crucible with an argon gas blanket to limit oxidation and nitrogen pickup. Heats 5 and 6 were made with lime-fluorspar and lime-alumina slags, respectively, in an unsuccessful attempt to reduce the sulfur content below 0.006%.

Table 1.—Composition of Experimental Steels

	Chemical composition, %								
Heat	*C*	*Mn*	*Si*	*Ni*	*Cr*	*Mo*	*S*	*P*	*Other*
1	0.33	0.76	0.26	1.91	0.83	0.25	0.005	0.008	...
2	0.45	0.64	0.33	1.88	0.82	0.26	0.008	0.005	...
3	0.59	0.66	0.29	1.93	0.81	0.26	0.006	0.007	...
4	0.46	0.66	0.20	1.94	0.83	0.26	0.037	0.026	...
5	0.46	0.77	0.25	1.89	0.90	0.24	0.008	0.004	...
6	0.46	0.69	0.21	1.83	0.82	0.21	0.006	0.004	...
8	0.14	0.88	0.55	1.77	1.00	1.00	0.007	0.006	0.19 V
9	0.15	0.78	0.51	1.73	0.93	1.03	0.031	0.026	0.19 V
11	0.40	0.76	0.22	1.84	0.83	0.24	0.015	0.012	...
12	0.35	0.77	0.23	1.84	0.81	0.23	0.036	0.011	...
1-H	0.20	0.67	0.30	2.07	0.91	0.38	0.008	0.010	...
5-J*	0.41	0.91	0.28	0.51	0.53	0.24	0.009	0.021	0.0015 B

* 2½ lb per ton of rare earths were added to an 0.022% sulfur steel. Steel was supplied by Metals Research Laboratory, Carnegie Institute of Technology

Heats 8 and 9 simulate a high-strength weld metal and were prepared in an induction furnace. Heat 8 was prepared from electrolytic iron, and heat 9 was prepared from ordinary scrap. Heat 5-J simulates the boron steel AISI 86B40 and is a basis electric heat.

Ingots from the above heats were forged and rolled into plate and rounds. This material was further processed to hot-tension specimens and welding wire.

Hot-Tension Tests

The purpose in making hot-tension tests was to determine the properties of the steels at elevated temperatures and to correlate these properties with cracking resistance. The literature survey revealed few data on this point. It seems reasonable to assume, however, that there is no one temperature, or temperature range, which should be identified with hot cracking. Temperature of cracking is no doubt a complex function of the composition of the weld metal, as well as of the pattern of stress build-up in the weld metal during cooling. A knowledge of temperature is important in arriving at the causes and remedies for hot cracking.

Other investigators have conducted hot-tension tests in their weld-metal cracking studies. None of them, so far as is known, simulated welding conditions by testing specimens during cooling from the solidus. Instead, the specimens were fractured during the heating phase of the cycle. In the current work, special equipment was designed to test the properties of the weld metals on the cooling cycle. A description of the apparatus is given below.

Fig. 1 Hot-tension-test assembly

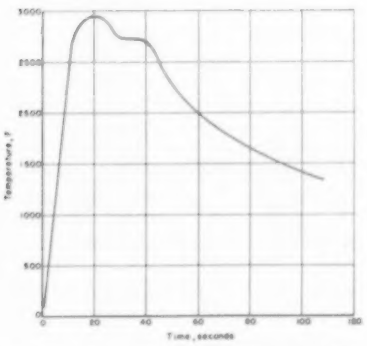


Fig. 2 Typical heating and cooling cycle used for hot-tension tests

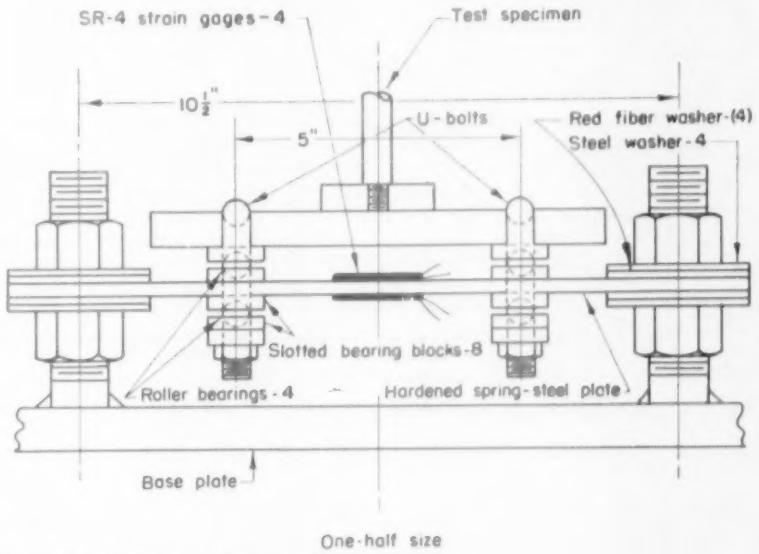


Fig. 3 (a) Weigh bar for measuring hot strength

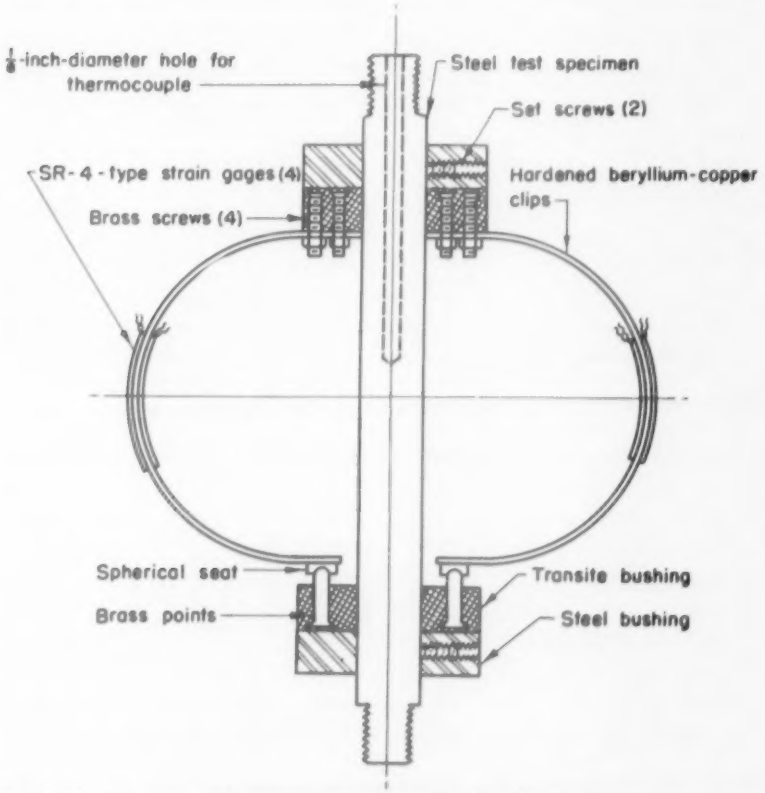


Fig. 3 (b) Clip-gage extensometer for measuring hot ductility

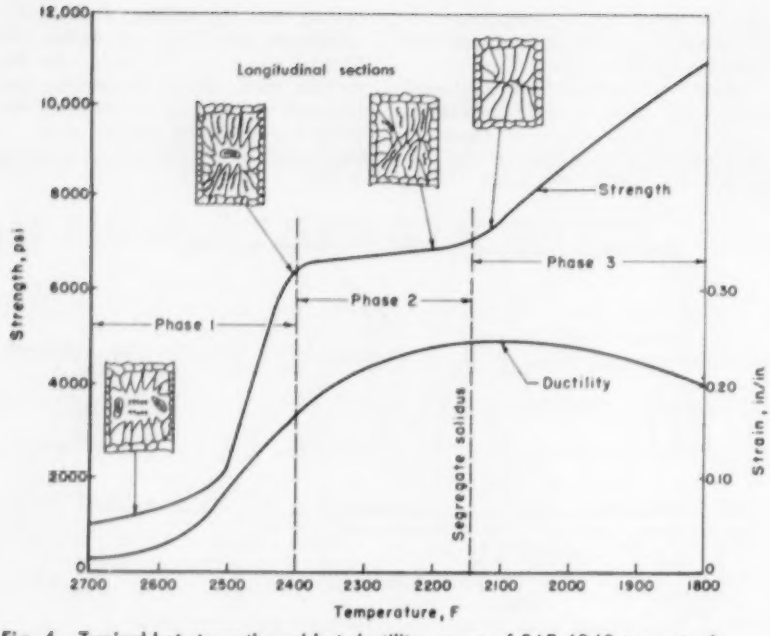


Fig. 4 Typical hot-strength and hot-ductility curves of SAE 4340-type steel

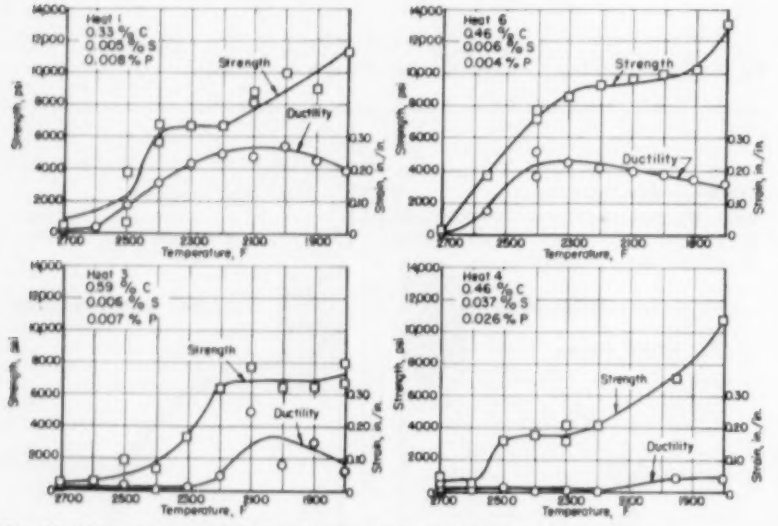


Fig. 5 Hot-tension properties of experimental SAE 43XX-type steels

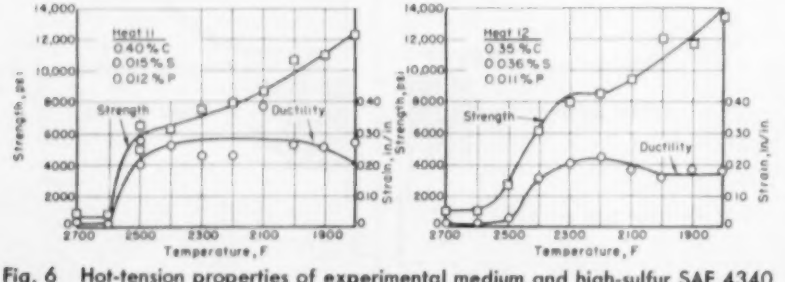


Fig. 6 Hot-tension properties of experimental medium and high-sulfur SAE 4340 steels

Equipment

The testing setup had to provide for rapid heating, the retention of the molten metal and the measurement of strength and ductility at elevated temperatures. The equipment is shown in Fig. 1.

Induction heating was chosen for two reasons: (1) to permit heating a small portion of the test specimen to high temperatures; and (2) to attain the steep temperature gradient during cooling that is present in an actual weld. A typical heating and cooling cycle is shown in Fig. 2. The evidence of a plateau at 2700° F indicates that the liquid phase of this material was reached, since the solidus and liquidus temperatures are within 100° F for steel of this carbon content.

The cross section and length of the hot-tension specimen were similar to the standard tension specimen. The temperature was measured with a platinum-platinum-rhodium thermocouple in the melted zone to obtain direct temperatures of the portion of the specimen under test. In this case, it was necessary to protect the thermocouple bead with porcelain tubing. During the test, temperature was read on a high-speed recording potentiometer. Since the hot-tension specimens were melted before fracture, the problem of retaining the molten portion of the specimen had to be overcome. Several refractories were tried as molds and silica were found to have satisfactory resistance against thermal shock.

Rapid loading of the specimen was obtained with an air cylinder. Nitrogen was passed into this cylinder which was used to deliver the required load. The apparatus for measuring hot strength and ductility is shown in the photograph of Fig. 1, and schematically in Figs. 3*A* and 3*B*. The weigh bar (Fig. 3*A*) was used to measure load, and the clip-gage extensometer (Fig. 3*B*) was used to measure elongation.

Test Procedure

The hot-tension specimen was heated and cooled according to the curve shown in Fig. 2. During cooling, the specimen was fractured at a predetermined temperature in the range from 2700 to 1800° F. Tests were usually conducted at 100° F intervals for each heat. At the instant of fracture, the elongation and strength were recorded on a two-stage Sanborn oscillograph. Plots of elongation and strength versus temperature are shown and discussed in the subsequent section. Elongation is expressed as strain in inches per inch over a 2-in. gage length, and strength is in pounds per square inch of cross section at the test temperature.

Test Results

The strength values obtained are high for the temperatures at which they were

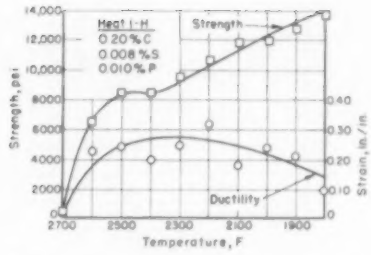


Fig. 7 Hot-tension properties of experimental SAE 4320 steel

recorded. The reason for this is that the surface of the specimen was at a lower temperature during cooling than the center where the thermocouples was placed. As a result, the surface of the specimen solidified giving some strength almost immediately after the power was turned off, while the core, where the thermocouple was placed, contained some liquid.

As mentioned previously, this apparatus was designed to test a metal under conditions that would simulate the cooling of a weld deposit. Before the test results are discussed, a brief description of the mechanism of solidification and how this mechanism is related to the shape of the hot-tension and hot-ductility curves is given. Typical hot-strength and hot-ductility curves are shown in Fig. 4.

These curves may be divided into three phases. The first phase begins at 2700° F; at this temperature, the steel is austenite and liquid. The outside edge of the specimen may be at a slightly lower temperature which accounts for the strength at this temperature. The strength and ductility do not increase any great amount until a temperature between 2600 and 2500° F is reached on cooling. Below this temperature, both properties increase until the beginning of phase 2 is reached. The high rate of increase in strength is partially the result of the solidification of the surface of the specimen. This cooling in the radial direction gives a severe temperature gradient across the specimen during cooling. However, during phase 1, there is some liquid in the core of specimens where the temperature is measured.

During phase 2, there are liquid films between the dendrites. As the temperature decreases, these films decrease in width until solidification is complete. At the beginning of this phase, the rate of cooling in the radial direction of the specimen has decreased considerably. From the appearance of the cast structure, however, most of the cooling during phase 2 occurs by conduction in the longitudinal direction (toward the ends of the specimens).

With this type of cooling, the low-melting liquid eutectic tends to segregate to the center of the heated portion of the specimen. Consequently, there is no substantial increase in cross sections of metal that have solidified. During this phase, the material in the core of the specimen has practically no strength, although it will permit straining before fracture, because the dendrites are joined partially along their boundaries. As the temperature decreases, the liquid films become smaller between the dendrites until solidification is complete. It is believed that hot cracking occurs during phase 2 of the tension and ductility curves, as shown in Fig. 4. The ability of the material to resist hot cracking depends on the amount of strain it will sustain without fracture during the period of solidification.

The metal is completely solid during the third phase. The strength increased with decreasing temperature. However, the ductility appeared to decrease. A possible reason for the apparent decrease in ductility, as shown in the curve, is that the length over which deformation occurs becomes smaller as the temperature decreases. This small length over which deformation occurs is no doubt the reason for the lower than normal values for ductility over this entire temperature range.

SAE 43XX-Type Steels. The hot-strength and ductility test results of six SAE 43XX-type steels are plotted against temperature in Figs. 5 and 6. The data are plotted to illustrate the scatter in the test results over the test-temperature range. Figure 7 shows the results of hot-strength and ductility tests of an SAE 4320 steel. The composition of the heats are shown in Table 1. A study of the curves for these steels shows that: (1) with decreasing temperature, hot strength increases from an almost zero value, then levels off (plateau), and finally increases again; and (2) with decreasing temperature, hot ductility increases from an almost zero value to a maximum, and then decreases slightly. This maximum usually occurs near the end of the plateau for hot strength.

It has been known for a long time that carbon and sulfur promote hot cracking. What has not been available is quantitative information linking poor hot strength and ductility with poor cracking resistance. It is believed that a start has been made in the direction of securing this type of information in the present study. Data were obtained on the effects of phosphorus, carbon and sulfur on hot-tension properties of low-alloy high-strength steels.

The effects of increasing carbon content on hot strength and ductility are shown in Fig. 8. The four heats whose properties are compared are 1-H, 1, 6 and 3. The carbon contents of these heats are 0.20, 0.33, 0.46 and 0.59%, respectively. Sulfur varies in these heats from 0.005 to 0.008%, and phosphorus from 0.008 to 0.010%. In other respects, the compositions of the four heats are almost identical. The increase in carbon content from 0.20 to 0.59% depressed hot strength and ductility, as shown in Fig. 8. The effect on hot strength was expected on the basis that the higher carbon steel has a lower solidus temperature than the lower carbon steel. The general displacement of peak ductility to a lower temperature as the carbon content was increased was expected on the same basis. However, the maximum duc-

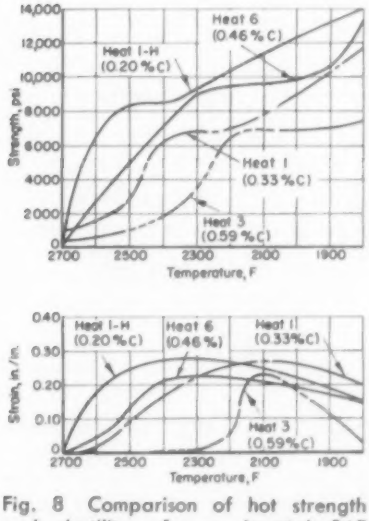


Fig. 8 Comparison of hot strength and ductility of experimental SAE 43XX-type steels, showing effect of carbon content P and S <0.010% in all heats

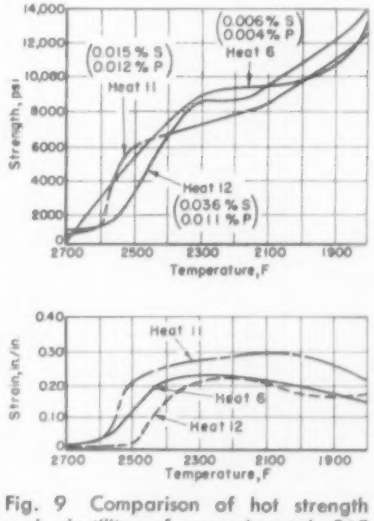


Fig. 9 Comparison of hot strength and ductility of experimental SAE 4340 steels, showing effect of sulfur content

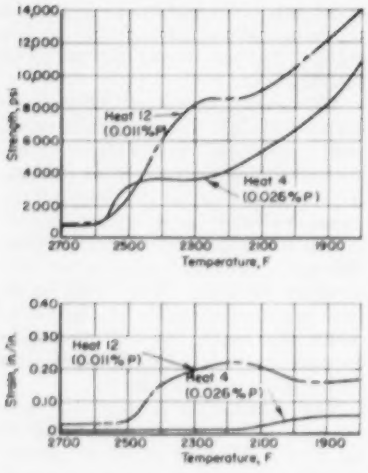


Fig. 10 Comparison of hot strength and ductility of experimental SAE 4340 steels, showing effect of phosphorus content

tility for heat 6 (0.46% carbon) occurred at a higher temperature than that shown for heat 1 (0.33% carbon). Perhaps the fact that the 0.46% carbon heat gave the better ductility at the higher temperatures is of more importance than the temperature at which maximum ductility occurred.

The results of increasing the sulfur content of low-phosphorus (less than 0.012% phosphorus) SAE 4340 steel from 0.006 to 0.015% and then to 0.036% are shown in Fig. 9. The heats whose hot-tension properties are compared are 6, 11 and 12. The hot-strength curves for the three steels indicate that the low-sulfur steel specimens solidified at the core of the specimen at approximately 1900° F and the medium and high sulfur at approximately 2100° F. These curves show little difference between the hot-strength properties of these three steels. Increasing the sulfur content of the steel, from 0.006 to 0.036% resulted in a decrease in hot ductility. The medium-sulfur steel exhibited the maximum ductility. By considering the first significant increase in ductility, the low- and medium-sulfur steels show similar properties, while the increase in ductility of the high-sulfur steel occurred approximately 100° F lower, as shown in Fig. 9. On this basis, one might suggest that the low- and medium-sulfur steels would show about the same cracking resistance and the high-sulfur heat would be the least crack resistant of the three steels.

Two SAE 4340 steels containing different amounts of phosphorus were studied: 0.011 (heat 12) and 0.026% (heat 4). Both heats were high sulfur, that is, the sulfur contents were 0.036 and 0.037%, respectively. The hot strength and ductility of these heats are shown in Fig. 10. Both properties are reduced as the result of the increase in phosphorus. It appears that phosphorus may be as detrimental as sulfur in weld metals. Other work on hot tearing in steel castings has shown that phosphorus may be as detrimental as sulfur.[3] From the strength versus temperature curves, it may be seen that the strength level at which the plateau occurred was higher for the low-phosphorus steel. There was also a marked difference in ductility between the two steels. The high-phosphorus high-sulfur steel showed a maximum strain of 0.005 in./in. over the test temperature range as compared with a maximum strain of 0.22 in./in. for the low-phosphorus high-sulfur steel. It may be that phosphorus depends on sulfur for its effect. In other words, phosphorus may act indirectly. From these curves one would expect that the high-phosphorus heat would be more crack sensitive than the low phosphorus. One investigator proposes that phosphorus affects hot cracking by influencing the segregation of sulfur.[2] However, the data in this study are too limited to draw any definite conclusions.

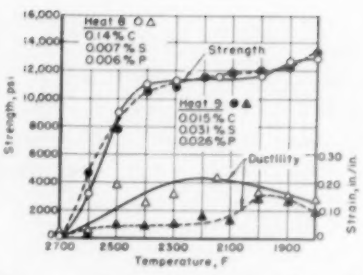


Fig. 11 Hot-tension properties of heats simulating a high-strength weld metal

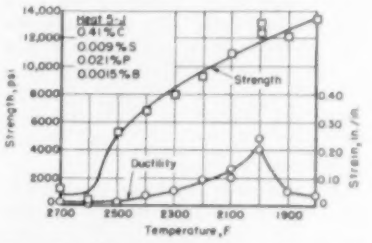


Fig. 12 Hot-tension properties of an experimental AISI 86B40 steel

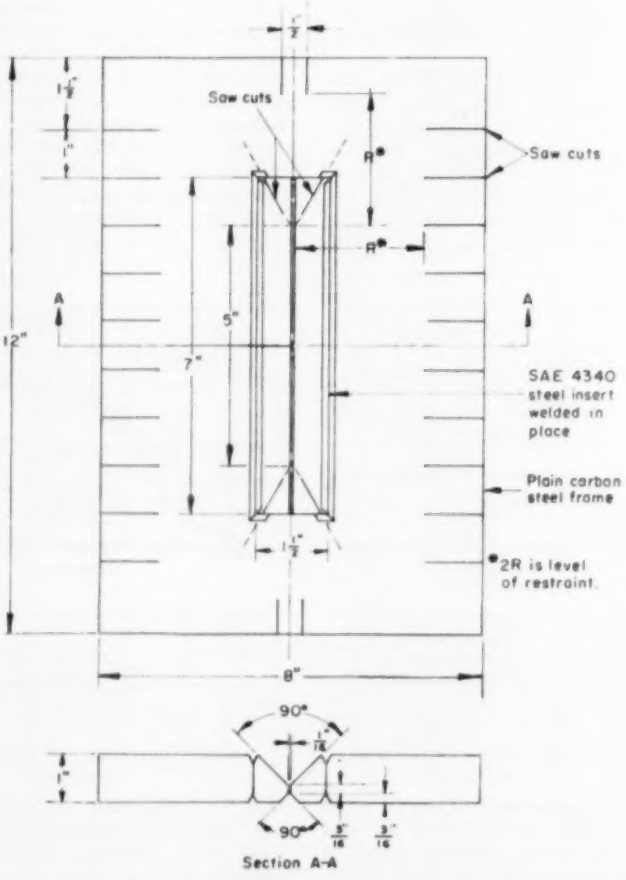


Fig. 13 Modified Lehigh restraint specimen

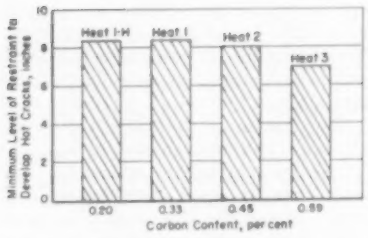


Fig. 14 Effect of carbon content on hot-crack susceptibility of low-sulfur-phosphorus SAE 43XX-type steels

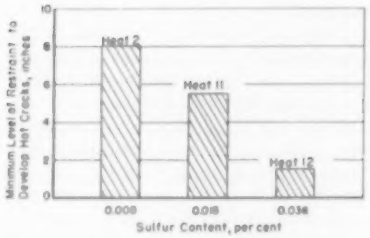


Fig. 15 Effect of sulfur content on hot-crack susceptibility of low-phosphorus SAE 4340 steels

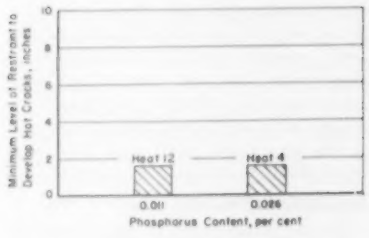


Fig. 16 Effect of phosphorus content on hot-crack susceptibility of high-sulfur SAE 4340 steels

Other Selected Steels. Hot-tension tests also were conducted on three steel heats (heats 8 and 9) simulating a high-strength weld and on a modified AISI 86B40 steel (heat 5-J). The compositions of the three heats are shown in Table 1. Heats 8 and 9 are low in carbon, 0.14 and 0.15%, respectively. The purpose of conducting the tests was to explore further the effects of high-sulfur-phosphorus contents on hot strength and ductility; also to determine these properties for a boron steel which may be used in lieu of SAE 4340. Heat 8 is low in phosphorus (0.007% phosphorus) and sulfur (0.007% sulfur) and heat 9 is high in these elements (0.026% phosphorus, 0.031% sulfur). The boron heat 5-J is high in phosphorus (0.031% phosphorus) but low in sulfur (0.009% sulfur).

The test results of the steels simulating a high-strength weld metal are shown in Fig. 11. The high-sulfur-phosphorus heat 9 exhibited less ductility over the entire test-temperature range than heat 8 which is low in the two residuals. Another important difference in the ductility of the two steels is that the maximum ductility for heat 8 occurred at a temperature approximately 200° F higher than was shown for heat 9. The hot-strength curves for the two steels are quite similar with the plateau and final solidification occurring at the same strength level and temperature. The hot ductility of the steel containing boron (heat 5 J, Fig. 12) is low until a temperature of 2000° F is reached. Between 2100 and 1900° F, the ductility increases from 10 to 20% at 2000° F, then shows a sharp decrease to 5% at 1900° F. Since a steel of this composition without boron was not investigated, it is not known whether the 0.021% phosphorus or the 0.0015% boron is responsible for this poor ductility.

Weld-Metal Cracking Tests

In order to evaluate the experimental heats of steels simulating weld metals on the basis of resistance to hot cracking, it was necessary to use some type of restraint specimen that would show differences in cracking susceptibility of the deposited weld metals. The cracking specimen would serve also as a guide in determining whether or not the hot-tension test was capable of detecting a material that would give a crack-sensitive weld deposit as compared with a weld deposit that showed very good crack resistance.

To evaluate the experimental heats of steel for crack sensitivity, it was believed that a specimen would have to be used that would offer various degrees of restraint on the deposited weld metal. There has been considerable work done with the circular-groove and circular-patch tests; however, both tests appear to be of the "go-no-go" variety. After a thorough review of the literature, it was decided that the Lehigh restraint test[4] might be the most satisfactory for this type of evaluation of weld metals. The circular-groove and circular-path specimens were used to a limited extent in the program, but the modified Lehigh specimen, referred to as the restrained weld tests, had two important advantages. These advantages were: (1) the fracture surfaces could be examined easily, that is, the color of the oxide film on the fracture surface gave an indication of the temperature at which cracking occurred; and (2) the restrained test was quite sensitive because it was possible to detect small differences in the crack sensitivity of the different weld metals. A drawing of the restrained weld specimen is shown in Fig. 13. The length of saw cuts in the frame determined the degree of restraint on the deposited weld metal.

The inert-gas-shielded consumable-electrode process was used to deposit

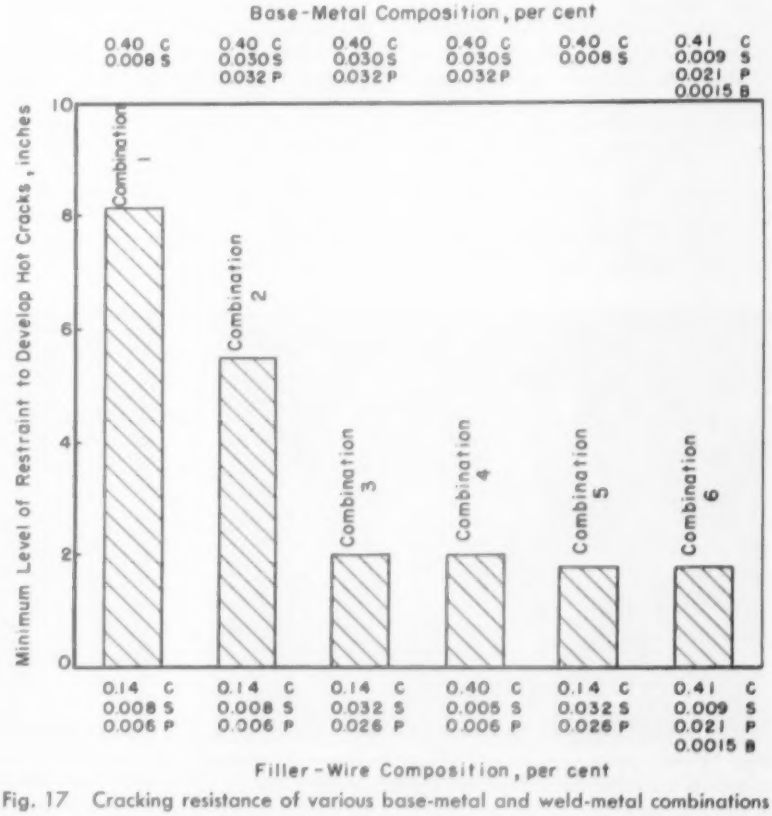

Base-Metal Composition, per cent
0.40 C 0.008 S
0.40 C 0.030 S 0.032 P
0.40 C 0.030 S 0.032 P
0.40 C 0.030 S 0.032 P
0.40 C 0.008 S
0.41 C 0.009 S 0.021 P 0.0015 B
Minimum Level of Restraint to Develop Hot Cracks, inches
Combination 1
Combination 2
Combination 3
Combination 4
Combination 5
Combination 6
0.14 C 0.008 S 0.006 P
0.14 C 0.008 S 0.006 P
0.14 C 0.032 S 0.026 P
0.40 C 0.005 S 0.006 P
0.14 C 0.032 S 0.026 P
0.41 C 0.009 S 0.021 P 0.0015 B
Filler-Wire Composition, per cent

Fig. 17 Cracking resistance of various base-metal and weld-metal combinations

the experimental weld metals because it is possible to deposit high-purity weld metals without contaminating them with elements from fluxes and other sources. A set of welding conditions was established at the beginning of the study and they were held constant throughout the test program.

Preparation of Welding Wire

In order to compare the results of the hot-tension and cracking tests, it was necessary to prepare the filler wires from the same heats of steels that were used in the tension tests. All of the wires were prepared at Battelle. The experimental heats were reduced to $^1/_4$-in. rounds by hot rolling; then cold drawn to $^3/_{32}$-in. round wire, the size used in the welding tests. Frequent annealing treatments in a controlled atmosphere were required during the drawing operation, which was quite time consuming for experimental batches. A chemical analysis of the wires showed that there was no pickup of impurities during the annealing treatments.

In the latter part of the program, the experimental wires were cold rolled from $^1/_4$-in. squares. The final product was $^3/_{32}$ in. square; however, it served quite satisfactorily as filler wires for use in the restrained weld tests.

Restrained Weld Tests

Two series of restrained weld tests were conducted. In the first series, SAE 43XX-type steel filler wire was deposited in the base plate of the same composition. In the second series, (*a*) wire from two heats (heats 8 and 9) simulating a high-strength weld metal was deposited in low- and high-sulfur SAE 4340 steel base plate; (*b*) low-sulfur SAE 4340 wire was deposited in high-sulfur SAE 4340 base plates; and (*c*) wire from an AISI 86B40 heat was deposited in base plate of the same composition.

Early in the program several of the experimental weld deposits would not crack at the higher temperatures (estimated to be between 1800 and 2700° F), but failed as the deposit cooled to room temperature. It was estimated that these cracks occurred between 400 and 1000° F. In order to distinguish this type of crack from the high temperature or hot crack, they were termed cold cracks in this study. Since the primary concern was to study hot cracking, a 200° F preheat was used successfully in all tests to prevent the cold cracking. After welding, the fractures were completed in a bending press and all cracks were examined for the dark-blue oxide color which characterizes a hot crack.

The results of the first series of tests on SAE 43XX-type steels are plotted in Figs. 14, 15 and 16. The plot in Fig. 14 shows that increasing the carbon content of low-sulfur-phosphorus SAE 43XX-type weld metal in the range from 0.20 to 0.59% causes a moderate decrease in cracking resistance. This work demonstrates that a weld metal of SAE 4340 composition can be deposited under severe restraint without hot cracking, provided the phosphorus and sulfur are at a low level. Increasing the sulfur content of low-phosphorus SAE 4340 weld metals in the range from 0.008 to 0.036% results in a pronounced decrease in cracking resistance, as shown in Fig. 15. The low-sulfur weld metal (0.008%) was deposited under severe restraint without cracking, while the high-sulfur weld metal (0.036%) cracked when deposited under slight restraint. The effect of increasing the phosphorus content of high-sulfur SAE 4340 steel from 0.011 to 0.026% is not clear from Fig. 16, because both low- and high-phosphorus heats 12 and 4, respectively, have such poor cracking resistance. The effects of phosphorus on hot cracking are being studied further by the preparation and testing of a high-phosphorus low-sulfur steel. This study should establish whether or not phosphorus is harmful in the absence of sulfur.

The results of the second series of cracking tests are plotted in Fig. 17. These results indicate that: (1) the weld deposits made with low-carbon-sulfur-phosphorus filler wires (combinations 1 and 2) are the most crack resistant, whether they are in low- or high-sulfur-phosphorus SAE 4340 base plate; (2) the low-carbon high-sulfur-phosphorus filler wires (combinations 3 and 5) have poor resistance to hot cracking, whether they are deposited in low- or high-sulfur-phosphorus SAE 4340 base plate; (3) the low-sulfur-phosphorus SAE 4340 welds deposited in high-sulfur-phosphorus SAE 4340 base plate (combination 4) have poor cracking resistance; (4) low-carbon low-sulfur-phosphorus welds made in high-sulfur -phosphorus base plate (combination 2) are more crack resistant than low-carbon high-sulfur-phosphorus welds made in low-sulfur-phosphorus base plate (combination 5); and (5) the boron steel (AISI 86B40, combination 6) has poor resistance to hot cracking.

In view of the excellent performance of low-sulfur-phosphorus SAE 4340 filler wire when deposited in base plate of the same composition (heat 2, Fig. 15), the poor cracking resistance of the filler wire, when deposited in high-sulfur-phosphorus SAE 4340 (Fig. 17, combination 4), was quite surprising. Selected welds were analyzed for sulfur, and it was found that the welds contained about 0.020 instead of 0.005% sulfur. The poor cracking resistance probably was caused by the contamination of the weld deposit with the sulfur and phosphorus from the base plate. It may be possible to reduce the amount of contamination, thus increase cracking resistance by altering the welding pro-

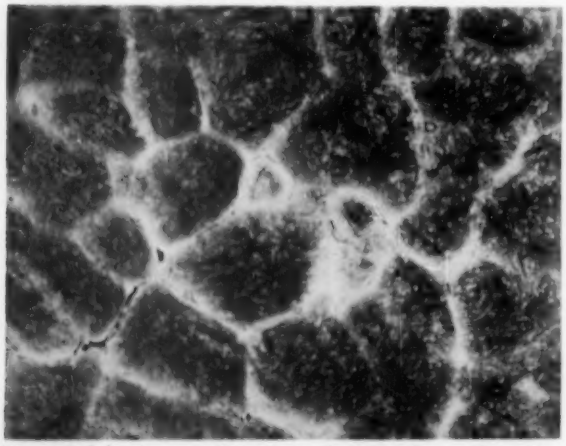


Fig. 18 (*a*) Area adjacent to fracture face of tension specimen (reduced by 25% upon reproduction) 250X

Fig. 18 (*b*) Photomicrographs of SAE 4340 steel (0.037% sulfur and 0.026% phosphorus) showing eutectic films in grain boundaries (reduced by 25% upon reproduction) 500X

cedures. However, this was not investigated in this study.

In general, the results of the restrained weld-cracking tests are in agreement with hot-tension data. For example, decreasing sulfur and carbon contents tend to increase hot ductility and resistance to hot cracking. However, the effects of a decreasing sulfur content on hot cracking (Fig. 15) seems to be more pronounced than the effects of these variables on hot ductility (Figs. 7 and 10). The effect of phosphorus on hot cracking requires further study in both the restrained weld and hot-ductility tests. The poor ductility of the boron steel (Fig. 12) is also demonstrated by the poor crack resistance when deposited under restraint.

Light-Microscope Studies

The isolation and identification of an intergranular eutectic in a crack-susceptible weld metal has never been accomplished, so far as is known. What makes a metal-arc weld deposit unique is probably the extremely high temperature in the arc, which is believed by some investigators to exceed the boiling point of the metal being deposited. Also, the cooling rate of the weld is usually very rapid. For these reasons, the patterns of freezing and segregation in a weld deposit might be expected to be unique.

A limited study with the light microscope was conducted on weld deposits and fractured hot-tension specimens. The chief purpose in making such a study was to uncover differences in the characteristics of grain boundaries and inclusions of crack-sensitive weld deposits and brittle hot-tension specimens, on the one hand, and of crack-resistant deposits and ductile specimens, on the other.

The light microscope was used to study the structures of hot-tension specimens and weld deposits. The hot-tension specimens, as well as the weld deposits, were either low- or high-sulfur phosphorus SAE 4340 steels. Microscopic examination of fractured hot-tension specimens revealed: (1) light-etching networks, which were shown to be rich in segregates; (2) nonferrous sulfides, such as manganese sulfide (MnS), precipitated in the light-etching network; and (3) intergranular films rich in iron sulfide (FeS). The identification of these films was confirmed by their anisotropic behavior under plane polarized light in all the high-sulfur-phosphorus SAE 4340 specimens observed. The location of these films in a high-sulfur-phosphorus SAE 4340 hot-tension specimen is shown in Figs. 18*A* and 18*B*. The area of the specimen shown in Fig. 18*A* was adjacent to the fracture face of the specimen. Cracks and fissures passed through the films in the grain boundaries. Figure 18*B* is a magnification of the central area of Fig. 18*A*. It may be seen from these photomicrographs that failure occurred in the boundaries that contained the greatest concentration of eutectic films. It will be recalled that all the specimens from the high-sulfur-phosphorus heat (heat 4), which had low hot-tension properties, were brittle in the 2700 to 1800° F temperature range. No films rich in iron sulfide were found in the low-sulfur-phosphorus specimens from heat 2, which had good hot-tension properties. Specimens from this heat appeared brittle at temperatures above 2300° F. However, the sulfur level was too low to detect FeS-rich films. A possible dependence of brittle fracture upon integranular eutectics, at least in the tension-testing phase of the work, is strongly suggested. "Eutectic" is meant to include compounds of one or more of the metallic elements nickel, chromium, molybdenum and manganese.

Photomicrographs of a section through the high-sulfur-phosphorus SAE 4340 weld deposit which had poor crack-

Fig. 19 High-sulfur-phosphorus SAE 4340 weld deposit showing inclusions and network (reduced by 25% upon reproduction) 100X

Fig. 20 High-sulfur-phosphorus SAE 4340 weld deposit showing nature of inclusions (reduced by 25% upon reproduction) 500X

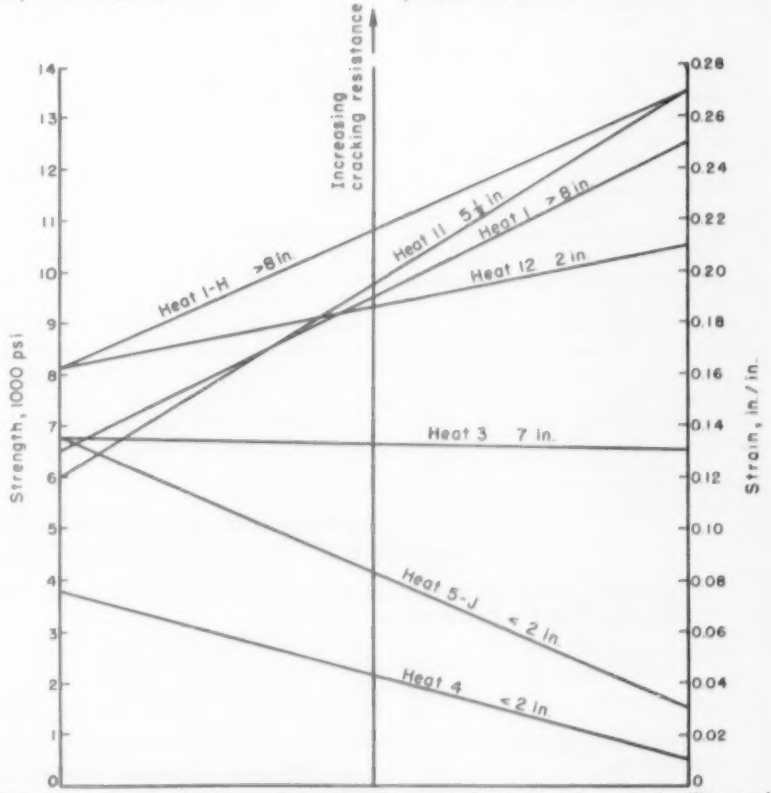


Fig. 21 Graph showing relationship between hot strength and ductility and cracking resistance of high-strength weld metals

ing resistance are shown in Figs. 19 and 20, at 100× and 500×. Light-etching networks can be seen in relief in Fig. 19. They probably are segregate-rich areas, just as in the hot-tension specimens. Three types of inclusions are evident in Fig. 20: (1) nonferrous sulfides (light); (2) silicates (dark); and (3) duplexed sulfide silicates. The inclusions occur as small, highly dispersed globules. There are apparently none of the film variety, and this is the important difference from the photomicrographs of the hot-tension specimen. The section through the low-sulfur-phosphorus SAE 4340 weld differs from the one just discussed by containing fewer sulfide inclusions.

Comparison of Tension and Cracking Test Results

This study showed a relationship between hot strength and hot ductility and the cracking resistance of high-strength weld metals. Enough hot-tension tests have been conducted, and the results have been sufficiently reproducible to advance a tentative explanation for hot cracking (in the particular steels studied so far) in terms of typical hot-strength and ductility curves. This explanation receives considerable support from the results of the weld-metal cracking tests.

The graph shown in Fig. 21 illustrates the relationship between the results of the hot-tension and weld-cracking tests. The hot-tension-specimen inserts for the cracking tests and the filler wires in each case were fabricated from the same heats of steel to enable a direct comparison of test results. The data shown in Fig. 21 were taken from the individual hot-strength and ductility curves shown earlier. The point on the curves at which the data were taken was the beginning of phase 3 of Fig. 4. This location was selected because it was believed that all of the low-melting constituents had solidified at this temperature; consequently, they would contribute to the mechanical properties of the steels. Those steels that exhibited poor hot-tension properties were also crack sensitive in most cases. There is a definite difference between those steels that exhibited poor hot-tension properties and those that gave good hot-tension properties and good cracking resistance. For example, heat 4 with a cracking resistance of less than 2 in., or very poor, has averages of 3800 psi strength and 0.01 in./in. ductility at the time complete solidification of the tension specimen was reached. Heat 1-H is an example of a crack-resistant steel. Its crack resistance is 8 in., or very good; the average strength at complete solidification is 8100 psi, and the average ductility 0.027 in./in. The remaining heats, with the exception of heat 12 (high-sulfur low-phosphorus SAE 4340), fall in one of two categories. This comparison would not be expected to show small differences in properties, but only to demonstrate difference between crack-sensitive and crack-resistant weld metals. From the data in Fig. 21, it appears that cracking resistance is influenced more by ductility than by strength. Heat 12 has relatively good hot-strength properties; however, its cracking resistance is quite poor (less than 2 in.). Since this heat appears to be out of order, one is led to believe that the hot-tension curves need to be checked.

In summation, the indications are that the following factors will be most important in determining whether or not hot cracking occurs: (1) the composition of the weld metal and the hot-tension properties of the metal over a critical temperature range during the cooling-down cycle; (2) the duration of this critical temperature range; and (3) the restraint imposed on the weld metal during cooling. Any methods applied to increase resistance to hot cracking would have to involve these factors.

Conclusions

1. The hot-tension test is very useful for determining the properties of alloys at high temperatures. The effects of small additions of alloying elements on the mechanical properties can be obtained. This piece of test equipment should be useful in studying the high-temperature properties of other alloys such as stainless steels, cast steels and high-temperature alloys that are sensitive to cracking at elevated temperatures.

2. Hot cracking occurs over a temperature range during which the hot strength and hot ductility do not increase at a sufficient rate to resist fracture of the metal caused by the shrinkage stresses from cooling.

3. A correlation existed between the cracking results obtained from the modified Lehigh restraint specimen and the hot-strength and ductility tests.

4. An increase in carbon from 0.020 and 0.59% in SAE 43XX-type steels showed only a small decrease in cracking resistance, while increases of sulfur and phosphorus from 0.006 to 0.030% showed a very pronounced decrease in cracking resistance.

5. Boron additions to steels of the compositions studied appeared to have a detrimental effect on the cracking resistance of the deposited weld metals; however, additional tests are required before the limits of boron may be established.

Acknowledgment

The authors wish to express their appreciation to the Wright Air Development Center, Wright-Patterson Air Force Base, for permission to publish this information.

Many members of the Battelle staff have contributed to this investigation. Those who were especially helpful are: C. B. Voldrich, A. J. Williams, C. E. Sims, S. L. Hoyt, O. E. Harder, D. C. Martin and R. W. Jech. Special acknowledgment is also due Major L. P. Marking and R. E. Bowman, of the Materials Laboratory, Wright-Patterson Air Force Base, for their assistance throughout the investigation.

Bibliography

1. Williams, A. J., Rieppel, P. J., and Voldrich, C. B., "Literature Survey on Weld-Metal Cracking," Summary Report, Contract No. AF 33(038)-12619, August 1951.

2. Rollason, E. C., and Roberts, D. F. T., "An Explanation of Hot Cracking in Mild Steel Welds," *Trans. Inst. Welding—Welding Research—BWRA*, **4**, (6) 129r–132r (December 1950).

3. Bishop, H. F., Ackerlind, C. G., and Pellini, W. S., "Metallurgy and Mechanics of Hot Tearing," *Trans. AFS*, **60**, 818–833 (1952).

4. Stout, R. D., Tor, S. S., McGeady, L. J., and Doan, G. E., "Some Additional Tests on the Lehigh Restraint Specimens," The Welding Journal, **25** (9), Research Suppl., 322-s to 331-s (1946).

Welding Research Council Bulletin No. 23
Cracking of Simple Structural Geometries

The Welding Research Council has just issued Bulletin No. 23, on this subject covering extensive investigations by the Ship Structure Committee on

(1) The Effects of Edge Preparation;
(2) Interrupted Longitudinal Members;
(3) Effects of Fastenings on Cleavage Fracture;
(4) Effect of Welded Pads on Tension Members.

This bulletin consists of 24 pages and is priced at $1.00 per copy. Limited Edition. Copies may be ordered through the

AMERICAN WELDING SOCIETY
33 West 39th Street, New York 18, N. Y.

TEMPER BRITTLENESS OF 1CR – ½MO WELD METAL

Investigation of weld failures in one of the first 1Cr – ½Mo catalytic-cracking reactors constructed shows definite evidence of temper brittleness

BY W. J. LESTER AND G. R. PRESCOTT

Introduction

The use of 1Cr – ½Mo for catalytic-cracking reactors has increased in recent years due to its resistance to graphitization, resistance to hydrogen attack, and its high allowable stresses at elevated temperatures. The alloy is considered to be readily weldable with electrodes of the same composition as the plate, provided the right preheat and postheat are used. But to date very little commercial experience has been published. This paper describes an investigation of weld failures in one of the first 1Cr – ½Mo catalytic-cracking reactors constructed. And it gives properties of 1Cr – ½Mo welds with several types of electrodes.

Background

The catalytic cracker had been in service at about 965° F and 20 psig for one year when cracks were noted at three locations. (1) At the toe and root of the fillet weld joining the manhole reinforcing pad to the shell. (2) At the toe of the fillet weld joining the feed inlet line to the shell. And (3) at the cone-to-standpipe weld. All of the failures were associated with changes in section thickness or changes in direction of stress.

The cracks were chipped out and rewelded. And the toe of the fillet welds were faired with a tungsten-arc inert-gas torch to provide a smooth transition and surface. Seventeen days after the reactor was on stream, weld failures again occurred. As before, the cracks were in the toe of the fillet welds of the manway and feed inlet, and in the cone-to-standpipe weld.

All of the original welding, and subsequent repairs, were made with an AWS E9015 electrode containing a nominal one percent chromium and one-half percent molybdenum. A minimum preheat and interpass temperature of 300° F was maintained during welding. And a 300° F preheat was used at the time the fillet welds were faired with the inert-gas tungsten-arc process. The welds were not stress relieved.

The alloy is considered to be readily weldable with electrodes of similar composition. Recommended[1, 2] minimum preheat varies from 200 to 400° F with stress relief in the 1150 to 1350° F range. Others[3] have found that 1Cr – ½Mo weldments will pass ASME code tests in the as-welded condition when welded with 300° F preheat.

Examination of Failures

The first failure involved a conventional fillet weld as made with lime-coated low-hydrogen electrodes. These electrodes require stringer-bead welds that are not conducive to smooth transition zones. No detailed examination was made of the first failure since it was obliterated during the course of repairing the vessel. Sections of the second failure were available for examination and testing

A cross section of the second failure is shown in Fig 1. The crack progresses from the toe of the weld through the vessel wall. The crack originated in the center of the transition zone that was produced by fairing with tungsten-arc inert-gas. The transition zone is shown in greater detail in Fig. 2.

Metallographic examination of the remelted zone revealed the presence of microcracks. Typical cracks are shown in Fig. 3. A small sliver of this metal was removed and bent 5° over a ⅛-in. radius. The effect of this small bend angle is shown in Fig. 4. Hardness measurements of this zone were as high as 360 DPH. These findings indicate that the presence of microcracks and low ductility were the primary causes of the second failure.

Weld Metal Properties

Samples of weld metal joining the nozzle to the shell were tested for tensile strength and impact strength. Since this weld was not faired with the tungsten arc, these samples show the mechanical properties of the 1Cr – ½ Mo weld metal after one year's service at 965° F. Three tensile tests were made—one in the as-received condition, one after stress relief at 1250° F, and one after stress relief at 1350° F. The results are listed in Table I. The stress-relief treatments are effective in reducing the tensile strength and hardness. The reduction-of-area shows an unusually large decrease as a result

Table 1—Tensile and Impact Tests on Weld Metal from Manway Fillet Weld

Condition	*TS, psi*	*YS, psi*	*EL, %*	*RA, %*	*Brinell hardness*	*Impact strength, charpy keyhole*
As-received	119,000	105,000	21	61	231	15,11
After 1250° F stress relief	105,000	76,000	*	*	219	14
After 1350° F stress relief	96,000	83,600	21	21	186	16

* Break occurred outside gage marks.

W. J. Lester and G. R. Prescott are associated with C. F. Braun & Co., Alhambra, Calif.

Presented at 1955 AWS National Spring Meeting held in Kansas City, Mo., June 7–10, 1955.

Fig. 1 Crack in the toe of the fillet weld × 2

Fig. 2 Crack in the zone remelted by inert-gas tungsten arc × 10

of the 1350° F stress relief. The cause of this may be due to a defect in the tensile specimen.

The results of four Charpy keyhole impact specimens are shown in Table 1. Two of the specimens were tested in the as-received state. The impact values of 15 and 11 ft-lb are abnormally low. And these impact properties did not improve as a result of stress relief at 1250 and 1350° F.

In order to obtain a comparison with the as-welded condition, impact tests were made on the weldmetal test welds of the same brand of electrode as used on the reactor. The test welds were made on remnant plate from the same heat of steel used to fabricate the reactor. The impact properties of specimens with and without stress relief are listed in Table 2. Note that the as-welded impact strength of 30 ft-lb shows significant decrease after stress relieving at 1350° F. This decrease indicates a susceptibility to temper embrittlement.

Table 2—Impact Test on Prepared Weld Metal

Condition	*Impact strength, charpy keyhole*
As-welded	29, 30, 31
After 1150° F stress-relief	21, 26, 26
After 1350° F stress-relief	22, 24, 24

Electrodes

The indication of temper brittleness in the 1Cr – $^1/_2$Mo electrode prompted a broader investigation of electrodes containing chromium and molybdenum as alloying elements. Six different electrodes were tested. The chemical analyses of their weld metal deposit are given in Table 3. Electrode A is the electrode that was used on the reactor. The three 1Cr – $^1/_2$Mo electrodes and the $^1/_2$Mo electrode are commercially available. The $^1/_2$Cr – $^1/_2$Mo and the $^1/_4$Cr – $^1/_2$Mo were special electrodes made for this investigation.

A modified Reeves test was used to evaluate the electrodes. This is a fillet weld restraint test. It was selected because it produces welds with similar stress conditions as the fillet welds that failed. Details of the restraint test are shown in Fig. 5. Weld Numbers 1, 2 and 3 are anchor welds and the numbers show the sequence of welding. The weld called the Test Weld is the last weld made. Of the

Fig. 3 Typical cracks in remelted zone × 250

Fig. 4 Remelted zone after slight bending × 250

Table 3—Composition of Electrode Deposits

	Electrode	C	MN	P	Si	S	CR	MO
A	1Cr–½Mo AWS E9015	0.07	0.46	0.020	0.35	0.007	0.89	0.62
B	1Cr–½Mo AWS E8015	0.08	0.73	0.013	0.41	0.007	1.00	0.40
C	1Cr–½Mo AWS E9016	0.12	0.73	0.016	0.26	0.005	1.09	0.47
D	½Cr–½Mo AWS EXX15	0.05	0.51	...	0.15	...	0.44	0.50
E	¼Cr–½Mo AWS EXX15	0.05	0.45	...	0.20	...	0.23	0.47
F	½Mo AWS E7011	0.07	0.58	0.015	0.26	0.007	0.01	0.43

Table 4—Reeves Test Results—High-Restraint Welds

Electrode	Preheat Temp., °F	TS, psi	YS, psi	EL, %	RA, %	Charpy impact, ft-lb*	Maximum Brinell hardness weldmetal
			1CR–½MO Electrodes				
A	300	110,000	65,300	24	59	29	285
	500	106,000	79,200	25	58	28½	251
	700	112,000	75,100	19	38	24½	246
B	300	102,000	78,600	24	57	39	265
	500	101,000	77,500	24	61	37½	250
C	300	110,000	93,800	16	41*	32½	250
	500	107,000	86,600	25	63	33½	250
			Lower-Chromium-Content Electrodes				
D	300	88,000	71,500	27	67	39	241
	500	83,000	67,500	28	69	37	218
E	300	82,500	67,000	28	65	44	221
	500	83,600	67,000	26	67	49	213
F	300	86,000	68,600	21	45	33	243
	500	88,700	71,400	24	63	37	235

* Flaw at break in tensile specimen.

NOTE—Tensile specimens were ASTM 0.250 bars. Impact specimens were Charpy keyhole-notched bars.

four welds, the Test Weld is the weld made under conditions of highest restraint. Weld Number 3 is made under somewhat lower-restraint conditions. Both the Test Weld and Weld Number 3 were used to evaluate the electrodes.

All of the welds were made on ASTM 301 Grade B plate. With Electrode A, preheat temperatures of 300, 500 and 700° F were used. On the other five electrodes, preheat temperatures of 300 and 500° F were used. Preheat and interpass temperatures were held to within plus or minus 25° F. All electrodes were carefully dried and used immediately after removal from the drying oven. An expert welder made the welds under close supervision. Every effort was made to maintain similar conditions of time and technique for each Reeves test.

The completed test welds were sectioned and examined for cracks. Following this examination, all-weld-metal tensile- and impact-specimens were machined from the weldment and tested. Hardness measurements were made on each weld.

The weld metal obtained from Electrode A was the only one that cracked. The cracks were found in the Test Weld made with 300° F preheat. A typical example of the cracks found in this weld is shown in Fig. 6. The Number 3 low-restraint weld made with Electrode A at 300° F did not crack. And the high-restraint weld made with the same electrode and a 500° F preheat was also free of cracks. No cracks were found in the welds made with the other five electrodes at preheats of 300 and 500° F.

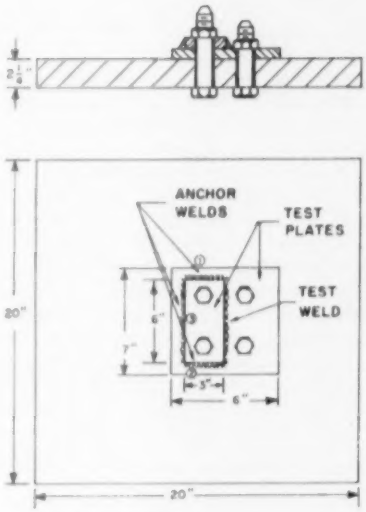


Fig. 5 Reeves test

The mechanical properties of the high-restraint welds at the different preheats are shown in Table 4. All of the 1Cr – ½Mo electrodes have as-welded tensile strengths above 100,000 psi at the preheats used in this work.

Electrode A exhibits some unusual effects of the 700° F preheat. Tensile and yield strengths at preheats of 700° F are higher than the weld preheated at 300° F. The weld metal preheated to 700° F shows a sharp decrease in elongation and reduction in area, and the impact strength decreases. Electrode B has consistent properties at both the 300 and 500° F preheat. This electrode has the highest impact properties of the three 1Cr – ½Mo electrodes. Electrode C exhibits the highest yield to tensile ratio at the 300 ° F preheat level with correspondingly low ductility. The same set of properties were obtained from the low-restraint Number 3 weld. The

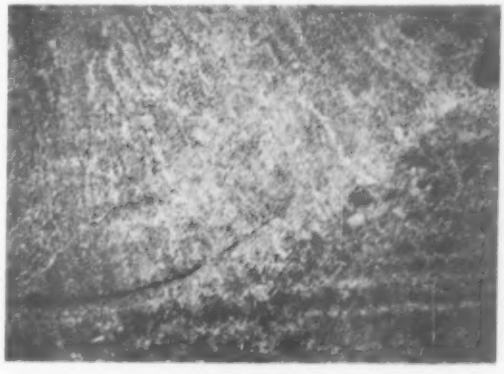


Fig. 6 Typical crack found in high-restraint fillet weld × 50

Table 5—Reeves Test Results—Low-Restraint Welds

Electrode	Preheat temp., ° F	TS, psi	YS, psi.	EL, %	RA, %	Charpy impact, ft-lb
		1CR–$^1/_2$MO Electrodes				
A	300	112,000		20	31*	25$^1/_2$
	500	109,000	67,400	23	45	25
	700	110,000	82,300	21	38	24$^1/_2$
B	300	99,100	67,000	23	59	31
	500	100,200	71,000	23	57	34
C	300	108,000	79,500	23	57	26$^1/_2$
	500	109,000	79,600	25	57	27
		Lower-Chromium-Content Electrodes				
D	300	84,000	62,500	27	69	41$^1/_2$
	500	84,900	65,000	28	73	40
E	300	82,000	65,300	34	71	50
	500	81,600	62,500	29	67	47$^1/_2$
F	300	82,400	62,900	16	30*	37
	500	82,900	67,600	19	43*	36$^1/_2$

* Flaw at break in tensile specimen.

results, listed in Table 5, show that this series of tests on the low-restraint welds follows the same general trend as the high-restraint welds.

The $^1/_2$Cr – $^1/_2$Mo and the $^1/_4$Cr – $^1/_2$Mo electrodes have about the same strength level as the $^1/_2$Mo electrodes. The lower chromium electrodes have better ductility and impact properties than the $^1/_2$Mo electrode.

Embrittlement Tests

The decrease in impact strength of Electrode A as a result of the 700° F preheat is further evidence of susceptibility to temper embrittlement. Previous indications were obtained from the effect of stress-relief treatments as shown in Table 2.

Another indication of temper brittleness is found by comparing the impact strengths of the low-restraint and high-restraint welds made with electrodes containing 1Cr – $^1/_2$Mo. These data from Tables 1 and 2 are rearranged in Table 6 for ease of comparison. All of the samples from the 1Cr – $^1/_2$Mo weld metal in the Number 3 weld had lower impact strengths than the Number 4 weld metal. There is a consistent decrease in the impact strength of the Number 3 weld as compared to the test weld. The reason is that Number 3 weld was made before the Number 4 weld. As a result, the Number 3 weld is subjected to its own thermal cycles, and to the thermal cycles produced in making the test weld. The net effect is a longer time in the embrittling temperature range. This comparison indicates that Electrode B and C are susceptible to temper brittleness to some extent under the conditions of the test. The lower chromium electrodes and the $^1/_2$Mo electrodes do not show this trend.

A service-exposure test was made with the weld metal from Electrodes A and B. The test consisted of exposing a set of Charpy blanks in the reactor for a period of ten months at an operating temperature between 930 and 960° F. Another identical set of blanks were stored at room temperature for the same period of time. The two sets of blanks were machined from a butt weld made with a preheat of 300° F. No stress-relief treatments were used. After the ten-month exposure period, impact tests were made on both sets of samples. The results are shown in Table 7. Electrode A again exhibits a decrease in impact-strength from 32 ft-lb to 25 ft-lb. Electrode B shows an increase in impact strength.

A final series of experiments were made to determine the effect of restraint on the susceptibility of Electrode A to temper brittleness. A Reeves-test weld was made at 300° F preheat. Then the entire assembly was held at 965° F for a period of 168 hr. Two sets of impact specimens were machined from the Number 4 high-restraint weld. One set was tested after the 965° F treatment for 336 hr. The second set of specimens were given an additional heat treatment of 1300° F for a period of 91 hr. The object of this treatment was to remove the embrittling effects of the 965° F treatment. The results are shown in Table 8. An average impact strength of 17 ft-lb demonstrates the adverse effect of holding in the temper-brittleness range under conditions of high restraint.

Table 6—Comparison of Low-Restraint and High-Restraint Weld Metal Impact-Strength

Electrode	Nominal composition	Preheat	—Impact-test results*— Number 3 weld, low restraint	Number 4 weld, high restraint
A	1Cr–$^1/_2$Mo	300	25	29
		500	25	29
		700	25	25
B	1Cr–$^1/_2$Mo	300	31	39
		500	34	38
C	1Cr–$^1/_2$Mo	300	27	33
		500	27	34
D	$^1/_2$Cr–$^1/_2$Mo	300	42	39
		500	40	37
E	$^1/_4$Cr–$^1/_2$Mo	300	50	44
		500	48	49
F	$^1/_2$Mo	300	37	33
		500	37	37

* Average of four tests.

Conclusions

Definite evidence of temper brittleness was found in 1Cr – $^1/_2$Mo weld metal. Three 1Cr – $^1/_2$Mo electrodes were evaluated by means of a Reeves restraint test. The results show that one of the 1Cr – $^1/_2$Mo electrodes, Electrode A, is mildly susceptible to temper brittleness under conditions of comparatively low restraint. The degree of susceptibility increases as the restraint increases. The other two 1Cr – $^1/_2$Mo electrodes, Electrodes B and C, show a mild susceptibility to temper brittleness under conditions of high restraint. Electrodes containing $^1/_2$Cr – $^1/_2$Mo, $^1/_4$Cr – $^1/_2$Mo, and $^1/_2$ Mo do not show evidence of temper brittleness.

Cracks were found in highly restrained welds made with Electrode A at 300° F preheat. No cracks were found in the welds made with the other electrodes under the same conditions of restraint and preheat. For welds made under high-restraint conditions, 300° F preheat is adequate for two of the 1Cr – $^1/_2$Mo electrodes and for the lower alloy electrodes. One of the 1Cr – $^1/_2$Mo electrodes, Electrode A, requires a 500° F preheat to prevent cracking.

Fairing the toe of 1Cr – $^1/_2$Mo fillet welds with inert-gas tungsten arc

Table 7—Service Test-Results

Electrode	After ten month's storage at at room temperature	Average	After ten month's in reactor at 930° F	Average
A	32, 29, 34, 32	32	25, 27, 27, 23	25
B	41, 47, 45, 47	45	50, 48, 49, 50	49

Table 8—Temper-Brittleness Test at 965° F

Specimen	Held 336 hr. at 965° F	Held at 1300° F for 91 hr after 336 hr. at 965° F
Reeves test weld metal, high restraint	16, 19	36, 42, 44
Reeves test weld metal, low restraint	21, 21	33, 38

produces hard brittle zones containing microcracks. Due to the extreme localization of the heat input from the tungsten arc, it is doubtful that increased preheat would be beneficial.

The welds in the reactor operated under conditions of high restraint and multi-axial stresses. In addition, the vessel was subjected to a severe thermal shock on start up. For these reasons, it is not possible to determine the contributing effect of temper brittleness to the failure. However, the trend toward decreased notch toughness is undesirable.

The selection of an electrode is governed by strength requirements, structural stability, and corrosion resistance. The ideal solution would be to produce a weld that matches the base metal in chemistry and mechanical properties. Since this is not possible, a compromise offers the best solution. Possible compromises for this application are the $^1/_2$Cr – $^1/_2$Mo electrode or the $^1/_4$Cr – $^1/_2$Mo electrode. The mechanical properties of these electrodes in the as-welded condition are close to the plate and they have adequate resistance to graphitization.

References

1. Stout, R. D. and Doty, W. D'Orville, "Weldability of Steels," Welding Research Council (1953).
2. *Steels for Elevated Temperature Service*, Booklet published by United States Steel (1949).
3. Bland, Jay, "Arc-Welding of Low Chromium-Molybdenum Steel Pipe," The Welding Journal, 32, 803-814 (Sept. 1953).

"FISH EYES" IN LOW-HYDROGEN WELD METAL

BY K. L. ZEYEN

Recent literature, especially in America, makes it clear that quenched weld metal may contain considerable quantities of hydrogen. These welds were deposited by low-hydrogen electrodes and contained "fish eyes." The following tests were made by the author with a high-quality lime-type low-hydrogen electrode, and confirm the American results.

Butt welds were made in $^3/_{16}$-in. steel plates in two ways: (*a*) every bead quenched in water immediately after deposition; (*b*) every bead allowed to cool to 212° F in air before the next bead was deposited.

All-weld-metal tensile and notch impact specimens were machined from each plate. One group of each was tested as welded. Another group of each was stress relief heat treated: (*c*) as (*a*) but stress relief heat treated; (*d*) as (*b*) but stress relief heat treated.

About one week elapsed between welding and testing. The hydrogen content of all specimens was measured 24 hr after welding.

The results in Table 1 show that quenching each bead increases the hydrogen content and causes fish eyes. Stress relief heat treatment lowered the hydrogen content and prevented fish eyes. It is very interesting that the notch impact value of the quenched weld, even after stress relief, was low for specimens cut from the root of the butt. The cooling rate during water quenching was more rapid in the root layers than in the top passes.

(Abstract of "Neuere Erkenntnisse über den Einfluss des Wasserstoffs bei Schweissungen," published in *Schweissen und Schneiden*, **7**, 200–207 (1955). The author, whose research is described herewith, is associated with the Research Laboratory of the Electrode Division of Oerlikon-Bührle & Co. Zurich-Oerlikon, Switzerland.) Abstracted by Dr. G. E. Claussen.

Table 1—Test Results

Specimen	Tensile tests: Yield strength, psi	Tensile strength, psi	Elongation in 5 diam., %	Reduction of area, %	Fracture	V notch Charpy values at −4° F, mkg/cm²: Upper layers	Lower layers	Hydrogen content measured at 480° F, cm³ per 100 g
a	79,100	84,500	7.2	22.5	Many fish eyes	15.1	6.6	2.7
b	69,000	80,000	29.2	72	Clean	15.6	13.3	0.2
c	68,000	80,500	24.6	62	Clean	12.0	7.0	0.16
d	70,400	78,000	27.0	73	Clean	17.0	15.1	0.11

FUSION WELDING OF 24S-T3 ALUMINUM ALLOY

General report of extensive research program and development with detailed data on the determination of the welding procedures required for successful production fusion welding of 24S-T3 alloy

BY J. B. ARTHUR

Introduction

In the design and construction of an airborne structure, weight and strength are of primary consideration from the standpoint of efficiency of the propelling system as well as the end use of the structure.

Any economically sound process or method of reliably joining the component parts, which results in a decrease in weight without penalizing the strength requirements of the structure is of paramount importance.

The use of fusion welding on such a structure results in design simplification, weight decrease, production economics, and material cost reduction provided such fusion welded joints are made sound and uniform and meet the strength requirements and special service requisites of the structure.

24S aluminum alloy has a good strength-weight ratio and has good elevated temperature properties (as compared to other aluminum alloys) as well as good overall physical properties. Its use on airborne structures is thus indicated.

The research work and results thereof reported herein are the end result of a concentrated team effort over a period of two and a half years by North American Aviation, Inc., Downey, Calif. toward the development of high strength uniform fusion welded joints in 24S-T3 aluminum alloy.

The program of research and development naturally was most extensive and covered a broad range of investigations of both base material and welded joints. To cover in detail the various investigations made in a paper of this nature is impossible; therefore, this paper is presented on the basis of a general report of the work done with detailed data on the determination of the welding procedures required for successful production fusion welding of 24S-T3 alloy.

J. B. Arthur is associated with North American Aviation, Inc., Downey, Calif.

Presented at Ninth Western Metal Congress held in the Ambassador Hotel, Los Angeles, Calif., March 28–April 1, 1955.

Statement of the Problem of Fusion Welding 24S-T3

Successful application of resistance welding processes in the fabrication of high strength aluminum alloys such as 14, 24 and 75 had been made. However, fusion welding had never been especially desirable from a strength or quality standpoint. As a matter of fact, these alloys were not recommended by aluminum producers for such processing.

The main difficulty in fusion welding is due to the broad thermal solidification range of this alloy and resultant loss of strength at the parent metal-weld metal interface due to loss of solution heat treatment. Table 1 has been compiled to illustrate the fusion weldability ratings of various aluminum alloys.

Table 1—Melting Ranges—Aluminum Alloys

Aluminum alloy	*Melting range,* F	*Difference,* F	*Weldability rating*
52S	1100–1200	100	3
56S	1055–1180	125	1
61S	1080–1205	125	2
14S	950–1180	230	4
24S	935–1180	245	5
75S	890–1180	290	6
43S	1065–1170	105	..

Table 2—Comparison of Joining Processes 24S-T3 Alclad

Process	*Thickness, in.*	*Physical properties—Ultimate strength, psi—Average*	*Maximum*	*Minimum*	*Range*	*% Elongation 2 in. G.L.*
Rivets	0.32	47,500	47,900	47,100	800	...
Resistance	0.064	30,600	31,900	27,200	4,700	115° Free bend
Seam weld	0.125	26,300	27,700	24,300	3,400	0.75
Resistance	0.032	47,900	No report	No report	No report	No report
Spot-seam-spot	0.040	49,030	No report	No report	No report	No report
	0.051	50,650	No report	No report	No report	No report
	0.064	52,650	No report	No report	No report	No report
	0.072	49,400	No report	No report	No report	No report
	0.081	54,650	No report	No report	No report	No report
Multi-arc	0.064	49,753	No report	No report	No report	2.3
(Cornell)	0.125	43,450	No report	No report	No report	1.0
Manual	0.032	38,600	44,400	33,500	10,900	1.5
Oxy-hydrogen	0.064	34,100	52,800	21,100	31,700	1.4
	0.081	30,400	40,300	14,900	25,400	1.3
Manual inert	0.032	53,300	59,200	37,700	19,500	2.0
Gas tungsten arc	0.081	47,300	49,800	40,700	9,100	1.0
Automatic	0.125	43,800	45,800	38,800	7,000	1.5
Inert gas						
Cons. elect.						
Automatic	0.032	54,300	59,400	51,700	7,700	2.5
Inert gas	0.040	46,800	48,500	41,200	7,300	1.8
Tungsten arc	0.051	46,600	49,000	41,600	7,400	2.0
	0.064	47,600	51,200	45,300	5,900	2.1
	0.072	48,100	50,000	45,500	4,500	2.3
	0.081	49,100	51,000	45,500	5,500	2.2
	0.125	47,000	51,100	42,800	8,300	1.8

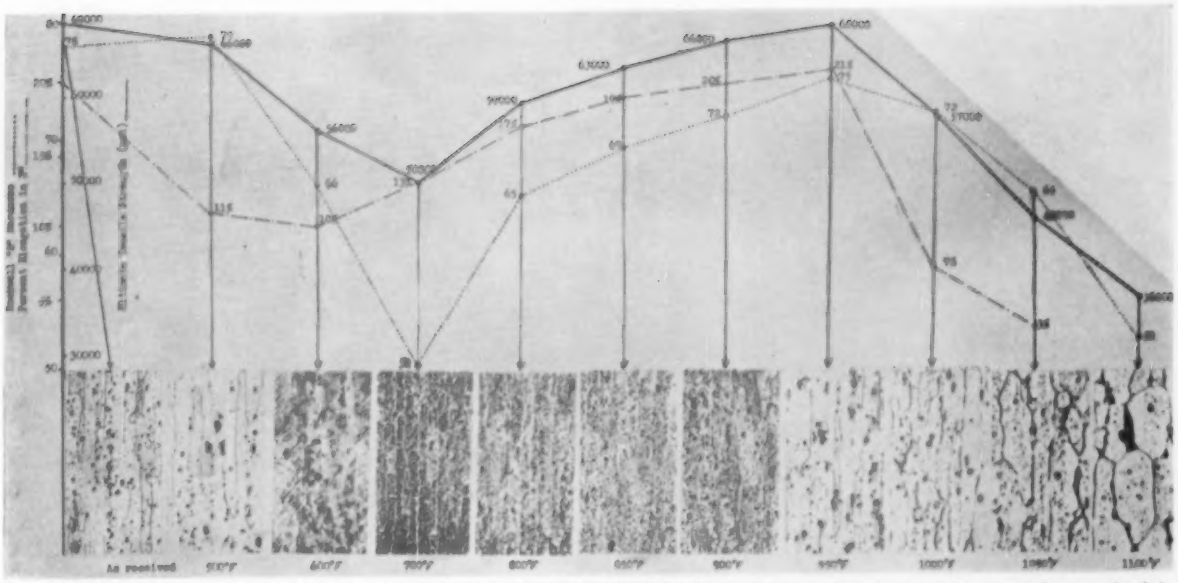


Fig. 1 Photomicrographs showing structural changes in Alclad 24S-T3 heated to various temperatures and quenched in water. Etched in Keller's Etch; original magnification × 250. (Reduced by 20% upon reproduction)

A comparison of the various methods of joining 24S-T3 was made in order to evaluate any of the details of the several processes which were perhaps common to all and which could be used in the application of the inert-gas-shielded tungsten-arc process (which is used successfully on the so-called weldable aluminum alloys). Table 2 shows a comparison of such processes.

Based on the above considerations, it was felt that the key to satisfactory fusion weld properties was in the use of the inert-gas-shielded tungsten-arc process used in conjunction with a high quench rate and with minimum heat transfer into the parent metal.

Metallurgical Investigation—Base Metal

Since the location of failure with the reinforcements left on under transverse tensile loading, initially, always occurred at the edge of the welds or at the transition zone from the weld metal to the base material, work was directed toward strengthening or increasing the properties at this zone. Factors involved in shifting this failure zone were investigated because it was felt that if the zone could be shifted, the mechanism of the shift would provide the answer to the strengthening problem.

In order to evaluate the properties of this zone, metallurgical investigations were made on the parent metal from the standpoint of various heat treatments and the establishment of a standard or base for comparison and correlation with weld metal structures.

Figure 1 shows the relationship between microstructure and mechanical properties of base material. The specimens which have alloying constituents in solution treated and naturally aged condition have high strength, hardness and ductility. Those which have alloying constituents in microscopically visible small coalesced particles or those which have overheated defects, such as grain boundary precipitation, eutectic melting and intergranular cracks have low strength and hardness. By comparing the structure of any specimen with that shown in Fig. 1 it is possible to evaluate approximately its mechanical properties.

A description of the various structures is as follows:

1. As received 24S-T3 sheet. Typical microstructure of 24S-T3 consists of hardening constituents principally of $CuAl_2$ (light), $Cu_2Mg_8Al_5$ or eutectic Al-$CuAl_2$—$Cu_2Mg_8Al_5$ (gray) and some Al, Cu, Fe, Mn, or/and Al, Fe, Mn, Si (dark) embeddded in a matrix of elongated grains of aluminum solid solution.
2. Up to 500° F the structure shows no gross structural changes.
3. At 500° F heated ½ hr and water quench, precipitation of dissolved constituents becomes apparent. This continues through 600° F and is practically complete at 700° F.
4. At 800° F re-solution of precipitated particles is noticeable.
5. At 850° F re-solution of precipi-

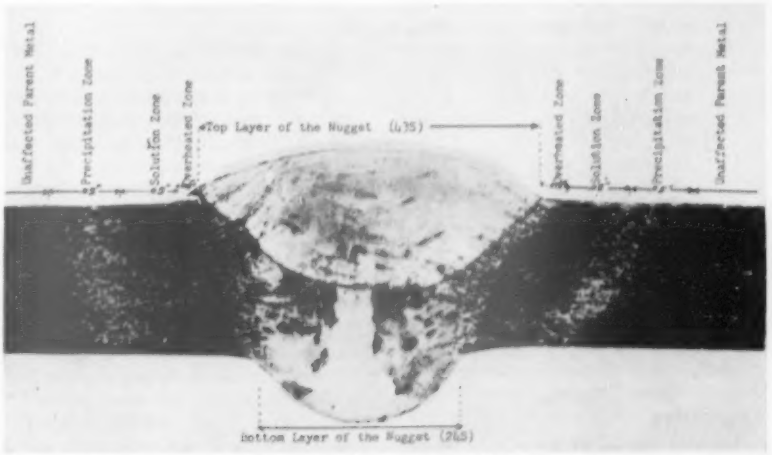


Fig. 2 Photomicrograph of a typical argon-gas-shielded tungsten-arc weld of Alclad 24S-T3 (0.125-in. thick sheet) showing the cast structure of the nugget and the heat-affected areas of the parent material. Etched in Keller's Etch; original magnification × 15. (Reduced by 50% upon reproduction)

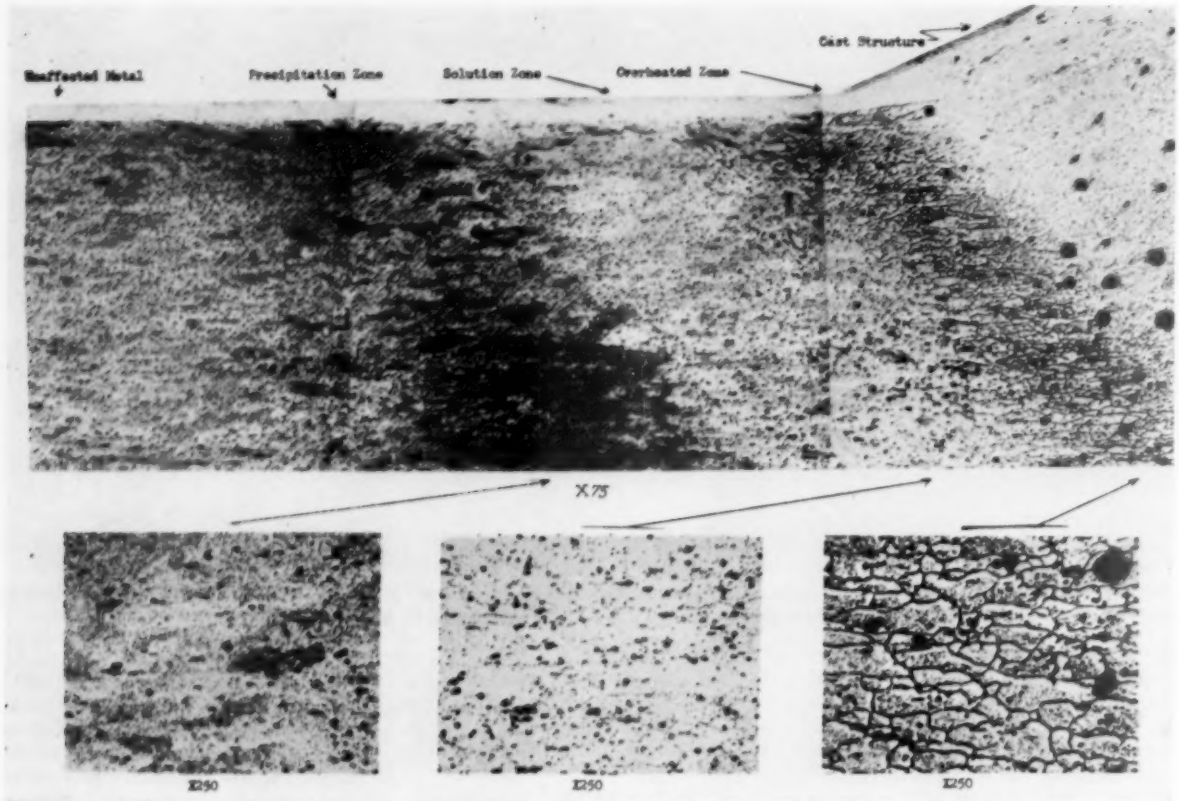


Fig. 3 Photomicrograph of multi-pass butt weld of Alclad 24S-T3 (0.125-in. thick sheet) showing the heat-affected zones adjacent to the weld nugget. Etched in Keller's Etch; original magnifications × 75 and × 250. (Reduced by 20% upon reproduction)

tated particles is very extensive.

6. At 900° F ½ hr and quenched re-solution is complete.
7. At 950° F with air cool the alloying constituents are precipitated, redissolved and partially re-precipitated.
8. At 1000° F with water quench the alloying constituents are rounded by heat treatment and eutectic melting is noticeable.
9. At 1050° F with H_2O quench intergranular cracks are formed and large round alloy particles re-precipitated at center area of grains.
10. At 1100° F with H_2O quench intergranular cracks and contrast between center area and edge of grains due to diffusion of constituents is pronounced.

These various structures were tested for physical properties and are as plotted on the figure.

Metallurgical Investigation—Weld Joints—Weld Metal, Base Metal Correlation

Initially, welds were made in square butt joints using a single pass with the addition of 43S filler wire under full automatic conditions. A great deal of trouble was experienced with porosity and a wide range of physical properties. Such trouble did not occur consistently and was not readily explainable in terms of joint preparation, welding machine settings, cleaning or other experimental variables. The solution to the problem was a two-pass welding sequence consisting of an initial pass without addition of filler metal and a second pass with the addition of filler metal.*

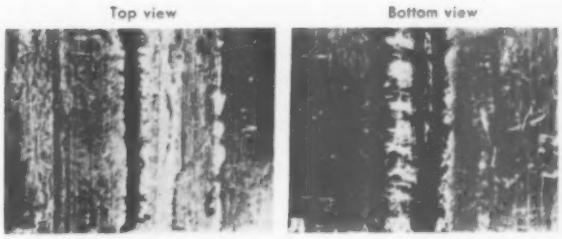
During the fusion pass a slight effervescence is noticeable indicating the release of gases that are otherwise trapped near the root of the weld when the filler wire is added on the first pass. (Regardless of its advantages the two-pass process does not eliminate the need for careful sheet preparation and the use of correct welding speeds). The use of two passes was of further benefit in the welding of 0.125 in. sheets in that it provided better control of the weld dimensions, particularly the drop-through. The amount of drop-through obtained on the first pass can be estimated closely by the concavity of the fusion zone upon resolidification. If the concavity is not more than barely perceptible, insufficient root penetration is a certainty. The amount of drop-through and the width of the weld are not appreciably affected by the second pass at normal amperages.

Regardless of welding procedure, however, all-welded joints consist of three zones: (1) weld metal (2) a heat-affected zone on each side of the weld metal and (3) base metal (see Fig. 2).

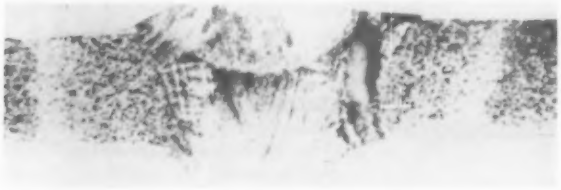
When 24S sheets are welded by the inert-gas-shielded tungsten-arc welding process (over a sufficient length) the flow of heat in the piece reaches a quasi-stationary state; that is, the isotherms representing the temperature distribution around the arc move as a constant pattern in the sheet during welding. The traces left on horizontal planes in the sheet, by different isotherms, are straight lines parallel to the direction of welding. As a consequence, the points at different distances from the electrode or the center line reach different maximum temperatures, and their microstructure is differently affected. The nature and extent of this heat effect in a normally produced 0.125-in. thick sheet is shown in Fig. 2. Figure 3 is an enlarged section of Fig. 2.

The weld metal, which consists of a cast structure, is formed by fusion of the filler wire and the base metal. The

* Some process details are covered by patent action of NAA.



Cross section; etched in Keller's Etch; original magnification × 10



Cross section of another weld; etched in Keller's Etch; original magnification × 10

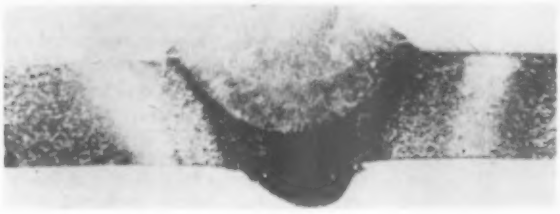
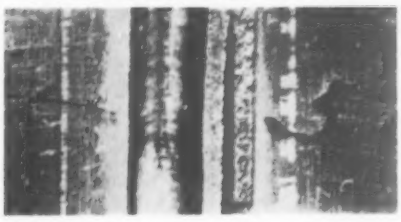


Fig. 4 Photomacrographs of inert-gas tungsten-arc butt weld of Alclad 24S-T3 tensile tested at room temperature; fractures occurred at the edge of weld (1) through cast structure and (2) through cast structure and overheated zone. (Reduced by 30% upon reproduction)

Top view; original magnification × 3



Cross section; etched in Keller's Etch; original magnification × 10 (reduced by 35% upon reproduction)

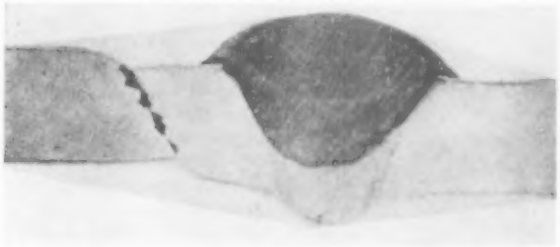


Fig. 6 Photomacrographs of inert-gas tungsten-arc butt weld of Alclad 24S-T3 tensile tested at 500 F; fracture occurred through parent metal at the precipitation zone

Top view; original magnification × 3

Bottom view; original magnification × 3

Cross section; etched in Keller's Etch; original magnification × 10

Fig. 5 Photomacrographs of inert-gas tungsten-arc butt weld of Alclad 24S-T3 tensile tested at room temperature; fracture occurred through cast structure and overheated zone

Top view; original magnification × 3

Cross section; etched in Keller's Etch; original magnification × 10

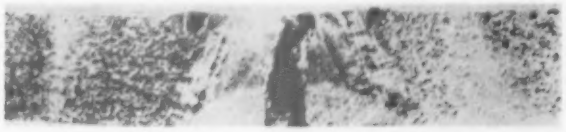
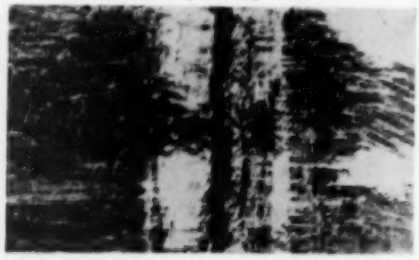


Fig. 7 Photomacrographs of inert-gas tungsten-arc butt weld of Alclad 24S-T3 flush ground and tensile tested at room temperature; fracture occurred at the center of weld through cast structure. (Reduced by 50% upon reproduction)

Top view; original magnification × 3



Cross section; etched in Keller's Etch; original magnification × 10

Fig. 8 Photomacrographs of inert-gas tungsten-arc butt weld of Alclad 24S-T3 flush ground and tensile tested at 500 F; fracture occurred at the center of weld through cast structure. (Reduced by 50% upon reproduction)

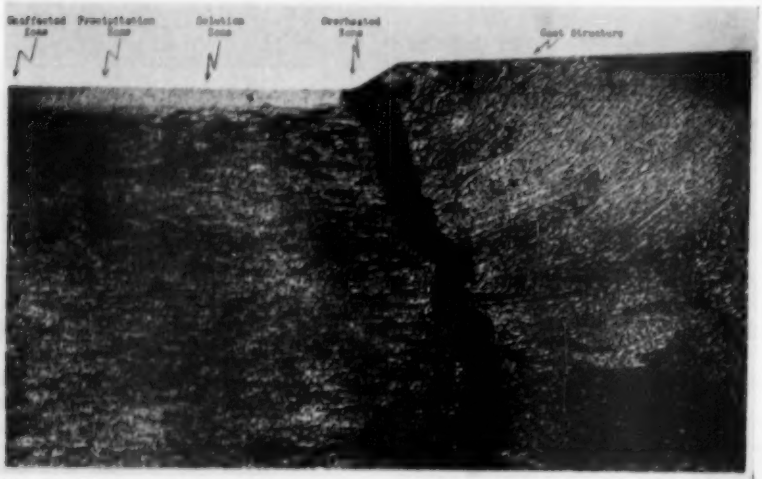


Fig. 9 Photomicrograph showing the location of fracture in a multi-pass butt weld of Alclad 24S-T3 specimen (0.125 in. thick) which was tension tested at room temperature. Etched with Keller's Etch; × 74. (Reduced by 50% upon reproduction)

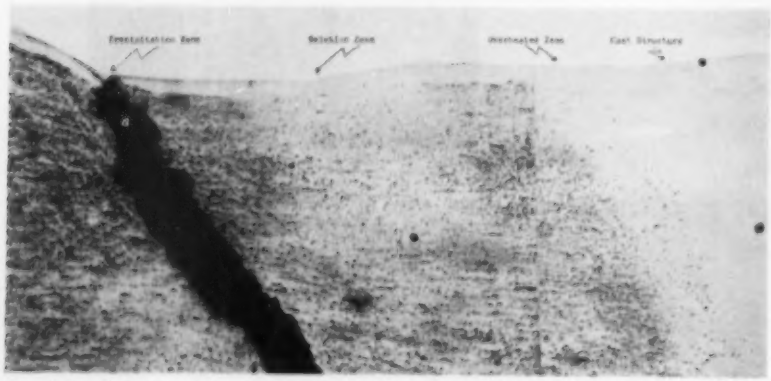


Fig. 10 Photomicrograph showing the location of fracture in a multi-pass butt weld of Alclad 24S-T3 specimen (0.125 in. thick) which was tension tested at 500 F. Etched with Keller's Etch; × 75. (Reduced by 50% upon reproduction)

lower portion formed during the first pass (fusing only) consists of the base metal 24S, and the upper portion formed during the second pass consists principally of the filler wire 43S.

The heat-affected area of the base metal on both sides of the weld metal contains three distinct zones, each zone blending gradually at its boundaries into the adjoining zones:

1. Overheated zone, approximately 0.015 in. in width, adjacent to the weld metal. The microstructure of this zone appears similar to that of the base metal samples heated to 1100° F, and water quenched. It contains grain boundary precipitation. The eutectic alloy particles are partially melted and resolidified. Sharp contrast is noticeable between center areas and edges of grains, caused by depletion of constituents by diffusion from the edge to the grain boundaries and precipitation of particles at the center areas. Some round black spots, probably due to high-temperature oxidation or puddle agitation and quick solidification around inert gas bubbles, are also noted. These are somewhat enlarged by polishing and etching technique.

2. Solution zone, approximately 0.05 in. in width at the center. The structure looks similar to that of the parent metal samples water quenched from 900–950° F. The dissolution of the precipitated alloying constituents is practically complete.

3. Precipitation zone, approximately 0.05 in. in width adjacent to the unaffected base metal. The structure appears similar to that of base metal samples heated to 700° F, but the precipitation is not so extensive or so complete.

Having now defined the zones as above, an examination of fracture locations in square butt welds is in order. Butt welds which are subjected to uniaxial tension load in the direction perpendicular to the weld line (transverse to rolling direction), usually fracture at the edge of the weld if tested at room temperature or in the base metal ($^1/_{16}$ to $^1/_8$ in. from the weld) if tested at elevated temperatures (500° F) provided the weld reinforcement is left on, otherwise the break pattern is identical through the weld metal itself. Figures 4 and 5 illustrate typical room temperature break patterns of 2 pass welds.

Figure 6 illustrates the 500° F break pattern in a 2 pass weld.

Figure 7 illustrates a room temperature break pattern with weld beads or reinforcements ground flush with base metal surfaces.

Figure 8 illustrates a 500° F break pattern with the weld beads or reinforcements ground flush with base metal surfaces.

It was further noted that at room

Fig. 11 Microstructure of a butt weld made by argon-shielded tungsten-arc welding process using Alclad 24S-T3 sheet and 43S filler wire. Etched in Keller's Etch; original magnifications × 15 for the nugget and × 250 for the blow-ups. (Reduced by 50% upon reproduction) →

temperature testing the fracture always started at the edge of the weld and either extended into the cast structure of the weld or remained in the overheated zone of the base metal (see Fig. 9). In 500° F testing, fractures usually remained in or near the precipitation zone of the parent metal (see Fig. 10).

These observations may indicate that at room temperature, the weld nugget and the overheated zone of the base metal at the fusion boundary are the weakest areas in strength as predicted above. At 500° F, the base metal particulary the precipitation zone, becomes weaker presumably due to the excessive coalescence of the precipitated alloying constituents.

Representative joint strength values obtained in tensile testing butt welded joints using 2 pass with 43S wire are shown in Table 3.

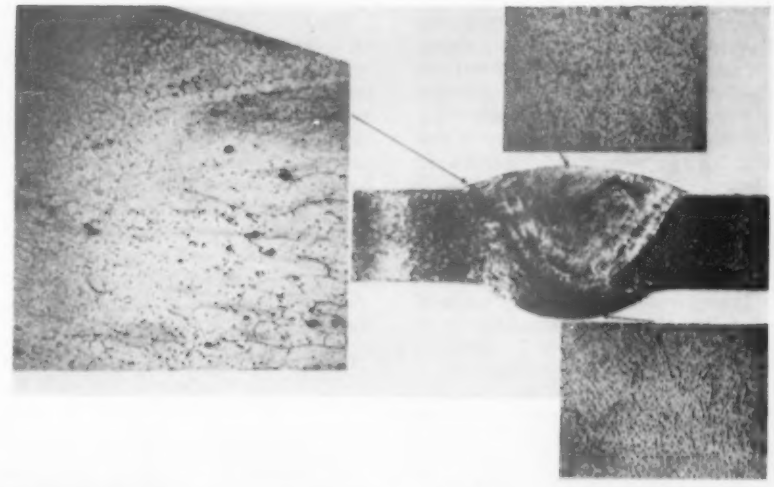
Figure 11 shows structure obtained using 43S wire.

Structures obtained using 24S filler wire are illustrated in Fig. 12 and the structure obtained using 356S filler wire is illustrated in Fig. 13.

The filler wire normally used in inert-gas-shielded tungsten-arc welding of Alclad 24S-T3 is 43S wire with a nominal composition of 5% Si-95% Al and a tensile strength of 20,000–25,000 psi in cast condition. Experimental joints were prepared by using conventional two passes with 43S, 24S, 356S and 56S filler wires. (Welds made using pure aluminum 2S filler metal cracked badly and are not covered in this report.)

It was noted that the joint strength of the welds made with various filler wires was similar and that small differences in the test values reported were below chance variations in testing and cannot be accounted for, except for 56S. The slightly higher joint strength reported for that filler material may be due to the relatively high strength of the filler material (approximately 42,000 psi) or to other assignable causes not recorded in testing (on the filler metal pass, utilization of arc power and variation in arc properties changes with filler metal used).

The structure of the weld metals for different filler wires was similar in appearance. It consisted of two layers. The bottom layer formed during the fusion pass, 24S in composition, and the top layer formed during the second pass



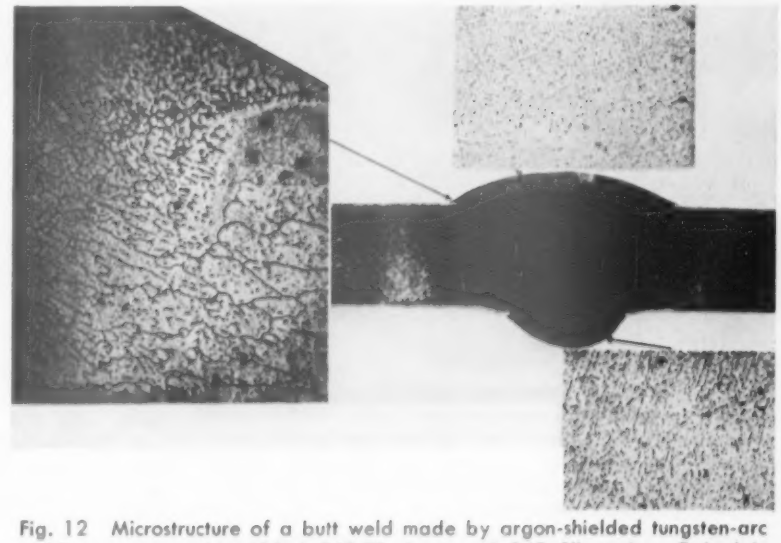


Fig. 12 Microstructure of a butt weld made by argon-shielded tungsten-arc welding process using Alclad 24S-T3 sheet and 24S filler wire. Etched in Keller's Etch; original magnifications × 15 for the nugget and × 250 for the blow-ups. (Reduced by 50% upon reproduction)

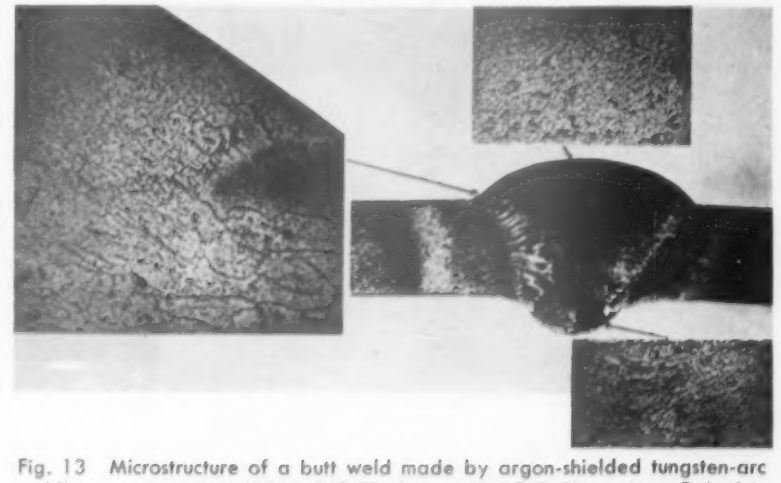


Fig. 13 Microstructure of a butt weld made by argon-shielded tungsten-arc welding process using Alclad 24S-T3 sheet and 356S filler wire. Etched in Keller's Etch; original magnification × 15 for the nugget and × 250 for the blow-ups. (Reduced by 50% upon reproduction)

different in composition for different filler wires. The coarse grain patterns were similar in all welds. The hardening constituents were of course different in composition for different filler wires, but they all were distributed as a network light in color or as scattered dark points.

Table 4 tabulates test data on welds made with various filler wires. Some experimental welds were made on special wires not covered in this paper.

The effect of the number of weld passes on properties was made.

Figure 14 shows a single pass weld vs. a double pass weld.

The structure of the beads in single pass welds consist of one layer with boundaries traversing the entire cross section of the base metal. In two pass welds, there were two distinct layers; one fused base metal layer at the bottom and the other filler metal layer on the top. In three pass welds (last pass fusion only), the third layer was not distinct, and the apparent size of the filler metal layer increased with the power used. At the higher power, the filler metal layer appeared to penetrate to the bottom surface of the nugget (Fig. 15). When the welding head was oscillated transversely to the joint during the third pass (see Fig. 16) or numerous fusion passes were employed the bead layers showed a complex boundary pattern (see Fig. 17). It is to be noted that there is a mechanical upset pattern at the edges of all welds. This varies with speed of travel and pass numbers.

The extent of the heat-affected zones slightly varied with different weld

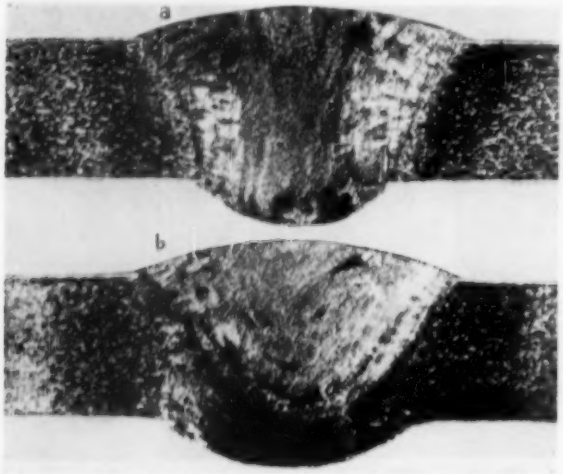


Fig. 14 Alclad 24S-T3 butt welds made by argon-shielded tungsten-arc welding process using (a) single-pass 175 arc amperes with 43S filler wire; (b) two passes 175 arc amperes first fusion only, second with 43S filler wire. Etched in Keller's Etch; original magnification × 15. (Reduced by 50% upon reproduction)

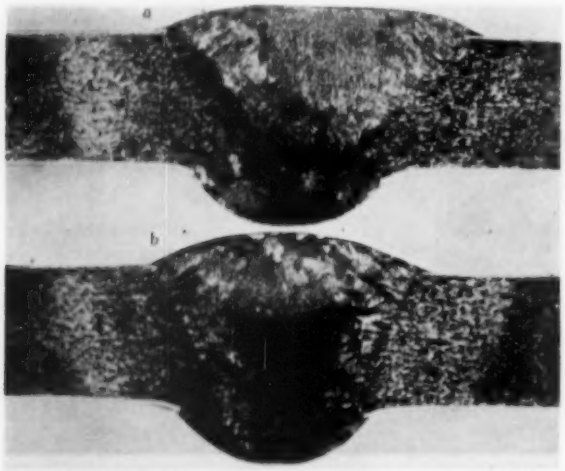


Fig. 15 Alclad 24S-T3 butt welds made by argon-shielded tungsten-arc welding process using three passes; first fusion only 175 arc amperes, second 175 arc amperes with 43S filler wire, and third fusion, (a) 175 arc amperes normal power, (b) 145 arc amperes low power. Etched in Keller's Etch; original magnification × 15. (Reduced by 60% upon reproduction)

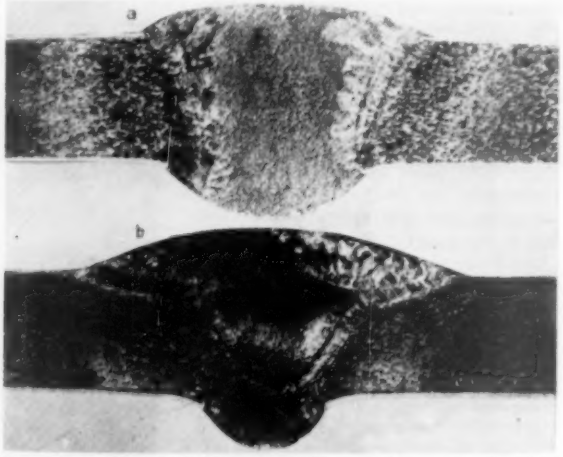


Fig. 16 Alclad 24S-T3 butt welds made by argon-shielded tungsten-arc welding process using three passes; first fusion only 175 arc amperes, second 175 arc amperes with 43S filler wire, and third fusion, (a) 195 arc amperes high power, (b) normal power with oscillation of the welding head. Etched in Keller's Etch; original magnification × 15. (Reduced by 60% upon reproduction)

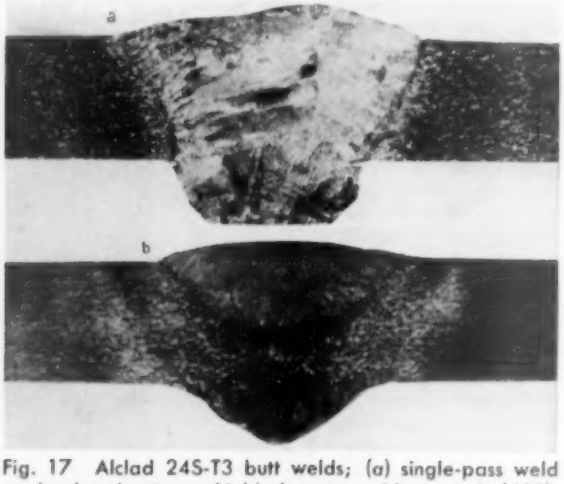


Fig. 17 Alclad 24S-T3 butt welds; (a) single-pass weld made by inert-gas-shielded consumable metal (43S)-arc, (b) fusion weld made by inert-gas-shielded tungsten arc without filler wire. Etched in Keller's Etch; original magnification × 15. (Reduced by 60% upon reproduction)

Table 3—Ultimate Tensile Strength Ductility Typical Welds at Room Temperature and at 500° F

	Beads on		Beads off	
Test temp.	*Joint strength, (psi)*	*% Elongation (in 2 in.)*	*Joint strength, (psi)*	*% Elongation (in 2 in.)*
Room temp.	54,500	5.0	44,500	2.0
	51,600	4.0	45,200	2.5
	46,600	2.0	43,800	2.0
	46,900	2.5	45,600	2.5
	53,100	5.0		
Average	50,540	4.6	44,780	2.3
500° F	33,600	3.0	32,300	2.5
	32,200	3.0	30,500	2.5
	32,800	3.0	33,000	3.0
	34,100	3.0	31,000	3.0
Average	32,930	3.0	31,700	2.8

Differences in average strength for the specimens with beads on from those with beads off are significant at room temperature tests, but below statistical significance level at 500° F tests. (All tests made on welds which were aged at R. T. 1 mo.)

condition, but no simple relation was apparent for the variation. The pattern was complicated by the oscillation of the welding head.

The joint strength values of the various welds are reported in Table 5. It is to be noted that the average joint strength for the single pass weld was smaller than that for multipass welds (10% or more) and that in three pass welds high arc ampere power somewhat tended to reduce the average joint strength (approximately 10%). The welds made with consumable electrode had low strengths. Small differences in the average joint strength for two and three pass welds were below chance variations in testing and were not significant.

The effect of heat treatment after welding was made.

Inert-gas-shielded tungsten-arc welding of Alclad 24S-T3 is normally processed without a preheat or postheat or any mechanical or thermomechanical action. The work is allowed to cool to room temperature by the aid of chill bars.

Observations made under controlled conditions indicate that joint strength increases with time if specimens are allowed to age naturally (Fig. 18). The areas in weld joints which reach above 700° F increase in hardness and tensile strength by natural aging. This fact and the possible adjustment or readjustment of residual stresses by aging are probably responsible for the increase observed in joint strength.

There is a slight increase (5–10%) in joint strength by artificial aging. The differences are slightly over chance variations in testing. The effect was, however, not consistently noticeable when the beads or the specimens were ground flush. (The weld metal, 43S, is not affected appreciably by aging as compared to the 24S base metal.)

Measurements of percent elongation in 2 in., which indicate the combined ductility of the weld metal and the adjacent base material, were not precise, but they seemed to indicate that artificial aging lowers that property under the test conditions.

Figure 19 shows the microstructure of the artificially aged weld and that of area adjacent to the weld metal. No change was noted in the microstructure of the weld metal, but the constituents in the base metal in heat-affected and

Table 4—Ultimate Tensile Strength vs. Filler Metal

		0.125 in. 24S-T3 Alclad						
					Test Temperature			
Filler metal	*Number of passes*	*Type and sequence of weld passes*	*Weld reinforcement*	*Artificial or natural aging*	*−300° F*	*+75° F*	*+300° F*	*+500° F*
43S	2	Straight fuse and filler	Not ground	Artificial				
				Natural	57,900	46,600	44,600	36,200
			Ground flush both sides	Artificial				
				Natural		42,200		
43S	3	Straight fuse, filler and fuse	Not ground	Artificial	63,900	56,600	50,600	29,900
				Natural	56,300	50,500	46,900	32,900
			Ground flush both sides	Artificial	54,800	48,500	44,800	28,000
				Natural	46,800	44,600	38,100	29,800
43S	3	Straight fuse, filler and weaved fuse	Not ground	Artificial	59,800	56,600	51,200	31,400
				Natural	57,600	53,700	48,200	34,800
			Ground flush both sides	Artificial	47,400	39,200	42,100	28,800
				Natural	41,800	40,300	36,100	29,600
24	2	Straight fuse and filler	Not ground	Artificial	62,500	52,500	50,700	31,300
				Natural	60,100	50,100	49,000	34,600
			Ground both sides	Artificial	56,800	46,600	45,100	30,000
				Natural	53,800	46,800	44,800	33,900
24S	3	Straight fuse, filler and weaved fuse	Not ground	Artificial		58,400		
				Natural		58,700		
356S	2	Straight fuse and filler	Not ground	Artificial	56,800	52,600	50,100	31,300
				Natural	51,500	48,900	45,900	34,500
			Ground flush both sides	Artificial	56,100	47,100	44,300	29,700
				Natural	42,900	44,000	39,900	32,000
56S	2	Straight fuse and filler	Not ground	Artificial		57,300		33,100
				Natural				
28	1	Straight filler	Not ground	Artificial		34,760		
				Natural		*		
716	1	Straight filler	Not ground	Artificial		26,250		
				Natural		34,000		
None	8	8 Fuse passes	Not ground	Artificial		61,400		
				Natural		†		

* Cracking occurred. † Range high.

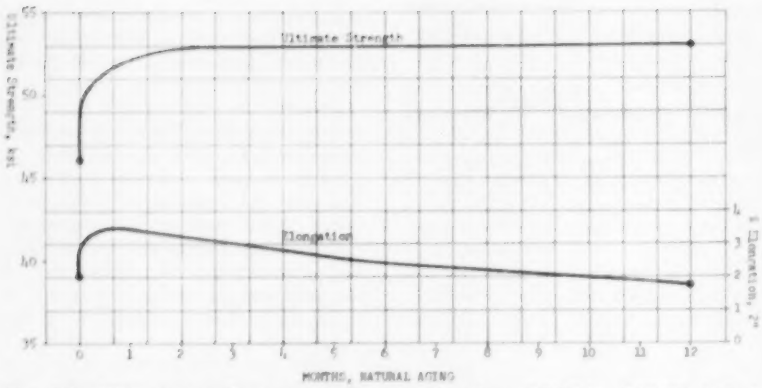


Fig. 18 Ultimate tensile strength vs. natural aging, 0.125 in. 24S-T3 Alclad automatic inert-gas tungsten-arc welded; Code MJ

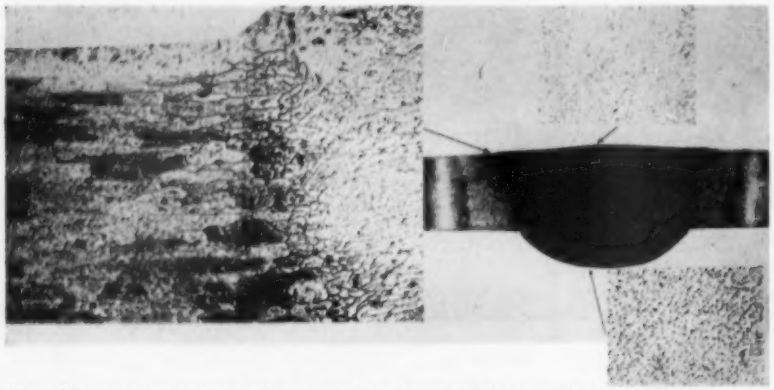


Fig. 19 Microstructure of an artificially aged butt weld made by argon-shielded tungsten-arc process using Alclad 24S-T3 sheet, 43S filler wire and conventional two passes. Etched in Keller's Etch; original magnification × 15 for the nugget and × 250 for the blow-ups. (Reduced by 50% upon reproduction)

unaffected areas, which were not visible under the microscope, became visible fine precipitates.

Solution treatment and aging of weld joints were made.

In general, extensive improvement in tensile strength of aluminum alloys has been accomplished by solution treatment and aging. The effect of such a heat treatment on joint strength is shown in Table 6.

It was noted that the heat treatment increased average strength from 16 to 32%. Fracture occurred in the base material $^1/_8$-$^3/_4$ in. away from the weld, except in the case of single pass welds which fractured at the edge of the head. The joint strength for single pass welds, although improved considerably by the heat treatment, was consistently lower than that for multipass welds. (Such strengths are comparable to results covered by Cornell Aeronautical Institute reports on "Multi Arc" welds.) Figure 20 shows a weld bead sheared from a panel and bent around. This is as welded plus solution heat treat and artificial aging.

The microstructure of the welds after heat treatment is shown in Figs. 21, 22, 23. It is to be noted that the three heat-affected zones previously observed in the base material were not present. Hardening constituents were precipitated as fine particles in the base material and also in the *bottom* layer of the nugget in multipass welds. The grain structure of the bead was still coarse, but the network of hardening constituents previously noted was completely dispersed.

A close examination of the overheated zones adjacent to the weld metal showed that large grain boundary precipitates were considerably reduced by diffusion during solution treatment. The diffused elements became visible in a network pattern by extensive artificial aging.

Superficial Rockwell T-20 hardness tests indicated that the hardness of the base material remained practically the same (62–68 Rockwell T-30), but the hardness of the nugget increased from 40–50 Rockwell T-30 to 60–65

Fig. 20 Weld bead ductility

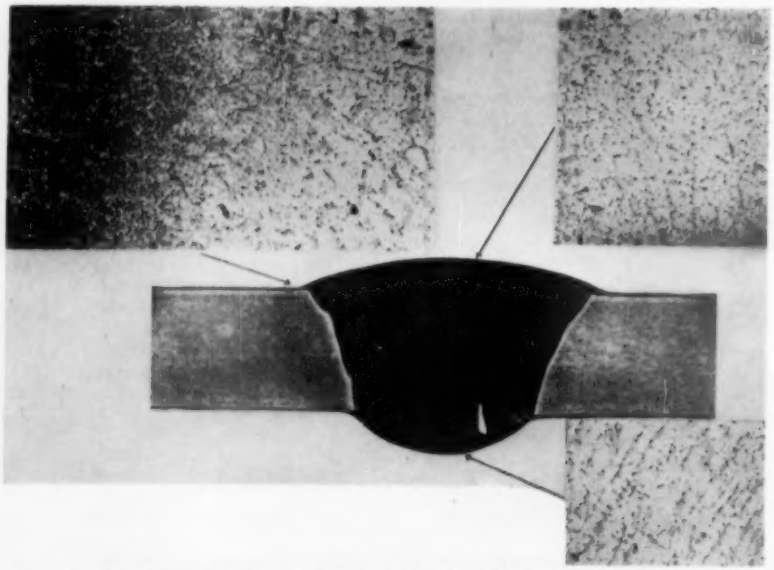


Fig. 21 Microstructure of a solution treated and aged single-pass welded made by argon-shielded tungsten-arc process using Alclad 24S-T3 sheet and 43S filler wire. Etched in Keller's Etch; original magnifications ×15 for the nugget and × 500 for the blow-ups. (Reduced by 50% upon reproduction)

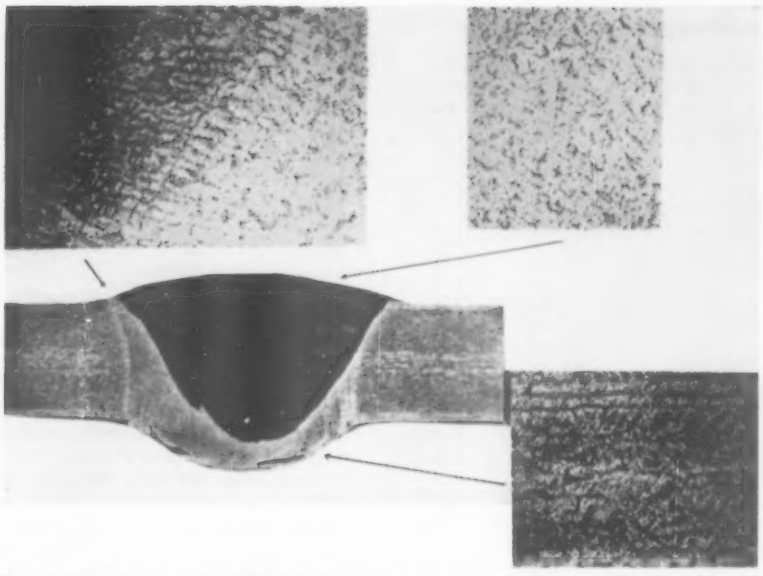


Fig. 22 Microstructure of a solution treated and aged conventional two-pass weld made by argon-shielded tungsten-arc process using Alclad 24S-T3 sheet and 43S filler wire. Etched in Keller's Etch; original magnifications × 15 for the nugget and × 500 for the blow-ups. (Reduced by 50% upon reproduction)

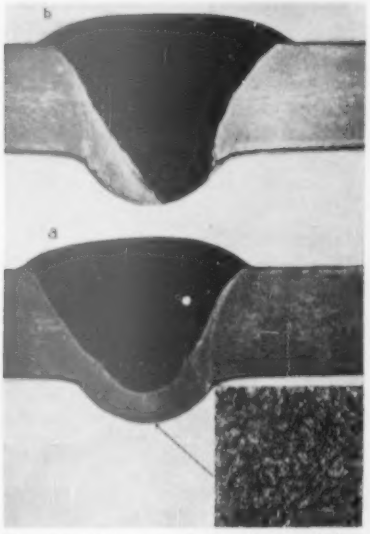


Fig. 23 Microstructure of a solution treated and aged three-pass weld made by argon-shielded tungsten-arc process using Alclad 24S-T3 sheet and 43S filler wire; (a) the third pass at normal power, (b) the third pass at high power. Etched in Keller's Etch; original magnifications × 15 for the nugget and × 500 for the blow-up. (Reduced by 50% upon reproduction)

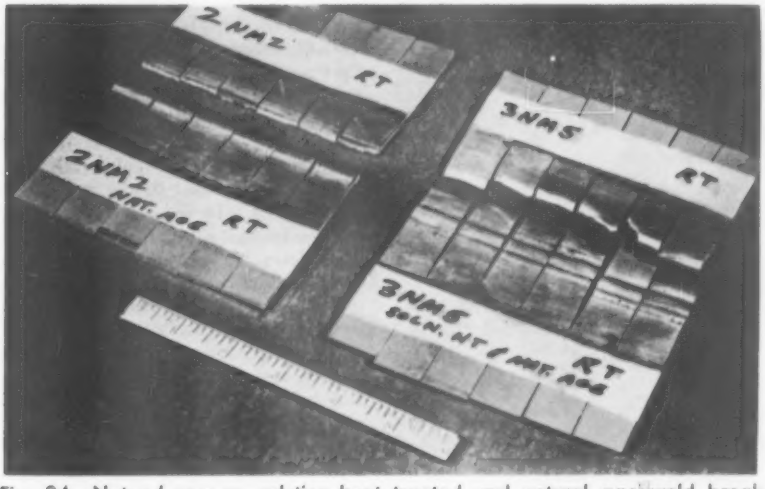


Fig. 24 Natural age vs. solution heat treated and natural age weld break locations

Rockwell T-30, practically the same as that of the base material.

To summarize—Fig. 24 compares break locations of artificial aging only vs. solution heat treatment and aging.

It was found that artificial aging slightly improved the joint strength (5–10%), but solution treatment improved it to a considerable extent (16–32%). It was thus possible to make joints stronger than the base material and shift the fracture, in tensile tests, away from the weld joints into the base metal.

Low strength of the weld metal was found to be related to coarse grain structure and a net work of alloying particles, and that of the overheated

		FTU, PSI	AV OF	RANGE	% EL 2"	AV OF	RANGE
TOP	A	37,400	5	3,300	1.1	5	1.0
	B	43,800	5	9,400	0.9	5	0.5
CENTER	A	42,500	6	6,000	1.8	6	1.0
	B	45,600	5	13,200	1.5	5	1.0
BOTTOM	A	37,200	5	9,800	1.5	5	1.0
	B	42,100	5	10,800	1.2	5	0.5

A = NATURAL AGE ONLY, ONE MONTH
B = AGED 375F 8 HOURS

	Si	Cu	Mg	Mn	Fe	Ti	Cr	V	Ni /0^3	Co /0^3	Al
24S NOMINAL	0.50 MAX.	3.8 4.9	1.2 1.8	0.3 0.9	0.05 MAX	0.05 MAX	0.10 MAX.	0.05 MAX	50.0 MAX	50.0 MAX.	REMAIN.
TOP	1.25	2.15	1.03	0.42	0.40	.017	013	015	2.8	4.1	REMAIN
CENTER (LONG SECT.)	1.28	1.85	0.82	0.35	0.32	019	018	.021	1.5	1.8	REMAIN
BOTTOM	1.30	1.70	0.87	0.33	0.36	019	022	020	19.0	1.8	REMAIN
*	0.77	3.0	1.30	0.49	0.37	028	020	023	3.8	1.0	REMAIN

* FRACTURED EDGE, TOWARD PARENT METAL

Fig. 25 Mechanical properties vs. chemical composition, automatic inert-gas tungsten-arc welded 0.125 in. 24S-T3 clad, three levels of weld cross section

Table 5—Effect of No. of Passes on Weld Tensile Properties

Test No.	*Welding Variable*	*Joint strength, psi*	*% Elongation (in 2 in.)*
I	Single pass with filler wire 180–185 arc amp	43,800	1.5
		45,100	1.5
		46,600	1.5
		45,400	1.5
		45,700	1.5
Average		45,100	1.5
II	Two passes at 175 arc amp first fusion only, second with filler wire	49,600	2.0
		49,300	2.5
		48,200	2.0
		53,100	4.0
		53,100	4.0
Average		50,700	2.9
III	Three passes at 175 arc amp first fusion only, second with filler wire, third fusion again	55,200	4.0
		49,200	2.0
		48,900	2.0
		56,700	5.5
		54,600	5.0
		53,500	3.5
Average		53,000	3.7
IV	Three passes same as III, except the third pass at 140 arc amp	54,200	3.5
		51,300	3.5
		53,600	4.0
		51,200	3.0
		47,100	2.0
		53,300	3.5
Average		51,800	3.3
V	Three passes same as III, except the third pass at 195 arc amp	47,100	1.5
		48,200	2.0
		47,100	1.5
		49,700	2.0
		46,600	1.5
		45,400	1.5
Average		47,400	1.7
VI	Three passes at 170 arc amp first fusion only, second with filler wire, third fusion with oscillation of the head	57,100	5.5
		53,700	3.5
		50,900	3.0
		56,400	5.5
		50,500	3.0
Average		53,720	4.1
VII	Single pass with consumable 438 electrode at 315 IPM wire speed 16 arc voltage 40 psi hold down pressure	46,000	
		44,900	
		42,200	
		47,500	
		44,800	
		42,700	
		44,200	
		37,800	
		44,700	
		34,400	
Average		42,920	

All fractures occurred at the edge of the weld or through the weld structure.

zone to the precipitation of alloying constituents at the grain boundary, depletion of alloying elements from the edge of the grains and partial melting and resolidification of the eutectic. Because of the stress concentration and residual stresses involved, it was difficult to evaluate whether the cast structure of the weld metal or the overheated zone (in the base metal) was weaker in strength. Indications were that the difference was slight. The properties of the overheated zone were not destroyed irreversibly as in so-called "burnt" alloys.

It is apparent that so long as the metal deposited in welds has a strength lower than the base material, the joint strength will always remain below the base metal even with a standard reinforcement. As the high strength in the base material and in most high strength aluminum alloys is achieved principally by solution heat treatment plus age hardening, the use of similar treatment in achieving high joint strength appears to be necessary.

The mechanical properties and chemical properties of a two pass weld by horizontal layers was made. Figure 25 shows this set of results.

Based on the above data, plus production necessities, tool requirements were set with the following basic requirements for all tooling to be used in conjunction with full automatic welding.

1. Uniform, consistent quenching of material adjacent to the weld must be provided. In order to obtain this continuity and contiguity between the hold down bars and shoes, the work (base material) and the back-up bars must be held and maintained for the complete linear length involved. Hold down bars must be parallel to each other and to the centerline of the groove in the back-up bar. Pressure must be uniform against the work and be precisely controlled and maintained for duplication of weld quality.

2. Material for back-up bars, hold down bars, and shoes must have high

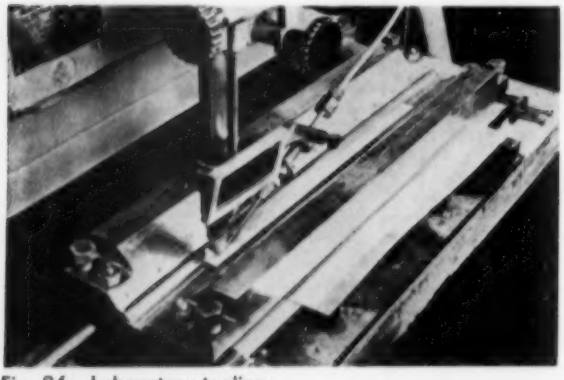


Fig. 26 Laboratory tooling

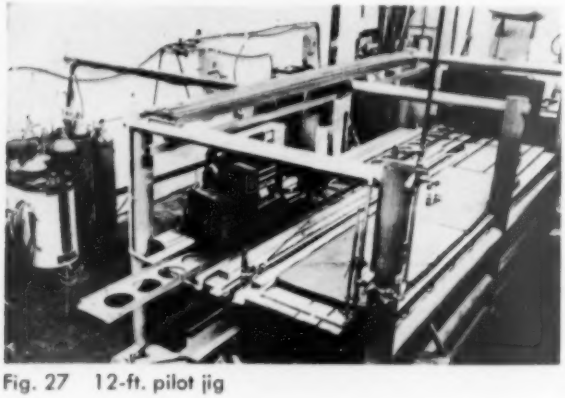


Fig. 27 12-ft. pilot jig

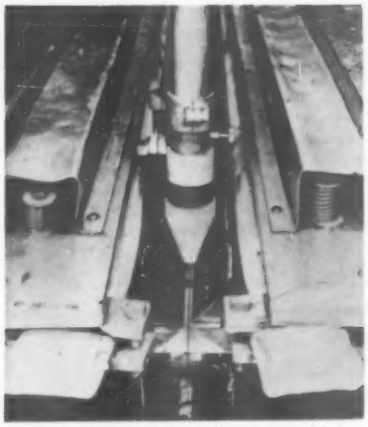


Fig. 28 Detail of 12-ft. pilot weld jig

thermal conductivity, not be weldable to aluminum or its alloys and have a fair degree of wear and abrasive resistance. It must also hold its shape under heat and pressure.

3. Jigs must be designed such that under operating conditions no distortion or deformation of the work occurs.

4. Jigs must duplicate consistently their mechanical actions.

5. Jigs must be rigid enough to prevent transmission of external shock or vibration loads to the work when welding is being done.

6. In the actual mechanical application of pressure down on the sheets there must be no movement for producing any lateral force which would result in an opening up or gapping of the seam. Actually it is desirable to have two components in this mechanical movement—a horizontal tightening (upset) of the seam and a vertical hold down pressure.

7. Loading and unloading time in line with the above requirements must be held to a minimum..

8. Operational maintenance as well as production operations must be simple and easy in order to facilitate use and also minimize nonproductive time.

9. The jigs must be adaptable for both sub-assembly and final assembly work.

Following preliminary work with simple tooling (see Fig. 26) in the welding laboratory, a 12-foot pilot test jig was built as shown in Figs. 27 and 28 and its use was directed toward determining welding procedures, weld joint properties, and final production tooling requirements.

At the same time as this work progressed, an investigation of all types and kinds of welding equipment, power supply, automatic controls, etc. was made.

The aims of the equipment investigation were based on the following requirements: (1) Joints of highest strength and greatest uniformity were required; (2) Highly skilled operators should not be required and (3) The welding jig design must not be unduly dependent upon the equipment used and could not be penalized economically due to use of such welding equipment.

The results of this equipment investigation finalized a decision to use a full automatic welding head, a balanced wave a-c transformer welder, an electromagnetic interlocking control panel with unit push button operation for all welding, a mechanically controlled variable speed wire feed motor, and a travel carriage with mechanical speed control.

Refinements were made to the equipment for very precise automatic control.

Table 6—Strength Data of Solution Heat Treated and Aged Welds

Joint strength of the welds made by argon-shielded tungsten-arc process with automatic machine using 0.125 in. thick Alclad 24S-T3 sheet, 43S filler wire and tensile tested to fracture after heating to 920° F for 45 min, quenched in water, and artifically aged to 375° F for 12 hr

Test No.	*Welding variable*	*Joint strength, psi*	*% Elongation (in 2 in.)*
I	Single pass with filler wire (180–185) arc amp	58,600	2.0
		58,200	2.0
		59,400	2.0
		58,300	2.0
		57,000	2.0
		58,700	2.0
Average		58,400	2.0
II	Two passes 175 arc amp each first fusion only, second with filler wire	63,800	5.0
		62,600	8.0
		62,400	7.0
		62,700	7.0
		62,200	7.0
		62,200	6.5
Average		62,700	6.8
III	Three passes 175 arc amp each first fusion only, second with filler wire, third fusion again	62,100	7.0
		62,100	7.0
		55,500	7.5
		62,400	7.5
		62,200	7.5
		62,500	8.0
Average		61,100	7.5
IV	Three passes same as III, except the third pass at 140 arc amp	62,800	7.0
		62,600	7.5
		62,200	7.0
		62,700	7.0
		61,900	6.5
		61,800	7.5
Average		62,200	7.1
V	Three passes same as III, except the third pass at 195 arc amp	63,100	7.5
		61,800	3.5
		63,200	7.5
		62,700	8.0
		63,200	4.5
		62,000	4.5
Average		62,700	7.1

Fractures occured in the base metal $^1/_8$–$^1/_2$ in. from the weld, except in the case of single pass welds which fractured at the edge of the weld.

EXPERIMENTS ON BRITTLE FRACTURE OF STEEL PLATES

High velocity dependence of the yield stress found to be the decisive factor in the brittle fracture of low-carbon steels

BY D. K. FELBECK and E. OROWAN

SUMMARY. Tensile tests at room temperature on ship-plate specimens provided with brittle edge cracks of various lengths are described. The fracture stress was found to be inversely proportional to the square root of the initial crack length. The initial brittle crack did not propagate directly as such but first changed into a very short fibrous crack, with considerable plastic deformation around its tip, and this changed back into a brittle crack.

The conclusion is drawn that the decisive factor in the brittle fracture of low-carbon steels is the high velocity dependence of the yield stress. If a cleavage crack propagates slowly, it requires under the conditions of the experiments large local plastic deformations for producing the necessary triaxiality of tension; it becomes a really brittle crack only when it runs so fast that the high velocity of any plastic deformation at its tip raises the yield stress there nearly or fully to the level of the cleavage stress, so that a considerable triaxiality of tension and the corresponding intense plastic deformations are no longer necessary.

1. Extension of the Griffith Theory

According to the Griffith theory of brittle fracture,[1, 2] the tensile strength of a brittle body containing a surface crack of length* c is

$$\sigma = \sqrt{\frac{2\alpha E}{\pi c}} \qquad (1)$$

if the body is a plate thin compared with the length of the crack, and

$$\sigma = \sqrt{\frac{2\alpha E}{c(1-\nu^2)}} \qquad (2)$$

if it is thick compared with c. In these equations, E is Young's modulus, α the specific surface energy of the surface of fracture, and ν Poisson's ratio.

These equations cannot be applied to brittle fracture in normally ductile steels, for the following reason.[3] In the Griffith theory, the surface energy α represents the work required for enlarging the crack, per unit area of additional surface of fracture. In a completely brittle material, fracture is not accompanied by any plastic deformation; in a low-carbon steel, however, a thin layer adjacent to the surfaces of fracture is plastically distorted, even though the fracture may appear quite brittle: this is recognized from X-ray back reflection photographs.[4] The cause of the distortion is easy to understand: the cleavage planes in neighboring grains do not intersect, in general, at the grain boundary, so that a cleavage in one grain cannot progress smoothly into a neighboring grain. As a rule, cleavage starts independently in several adjacent grains, and the process of separation is then completed by tearing involving plastic deformation at the grain boundaries. In an annealed or hot-rolled steel the X-ray diffraction spots from the individual grains are normally sharp; the intensity of the plastic distortion at the surface of fracture, therefore, can be estimated from the diffuseness of the spots in back-reflection photographs. The effective thickness of the cold-worked layer can be obtained from the rate at which the diffraction spots in successive X-ray photographs become sharper as more and more material is removed by etching from the surface of fracture (Fig. 1 *a*, *b*, *c*). Previous estimates of this kind[4] have led to the order of magnitude of 10^6 ergs/cm² for the plastic distortion work in the brittle fracture surface of a ship steel broken at room temperature; the steel from which the photographs shown in Fig. 1 (*a* to *c*), were taken gave a probable value of about $2 \cdot 10^6$ ergs/cm².

In general, the Griffith theory can be applied only if no plastic deformation occurs during the fracture process. However, if the deformation is confined to a layer at the surface of fracture the thickness of which is small compared with the length of the crack, the plastic work is proportional to the area of the surface of fracture and its value per unit area can be added to the surface energy, since their sum is the total work required for enlarging the area of the crack wall by unit amount. According to the X-ray investigations just mentioned, the effective thickness of the cold-worked layer is of the order of 0.3 or 0.4 mm, which is far above the usual lengths of Griffith cracks in completely brittle materials like glass. However, brittle fracture in low-carbon steel at or around room temperature cannot start without the presence of a crack or a notch far deeper than the thickness of the plastically deformed surface layer; it seems justified, therefore, to assume that the plastic surface work can be taken into account by adding its value p per unit area to the surface energy in the Griffith equation. In this way, eq 1 becomes[16]

$$\sigma \cong \sqrt{\frac{E(\alpha + p)}{c}} \qquad (3)$$

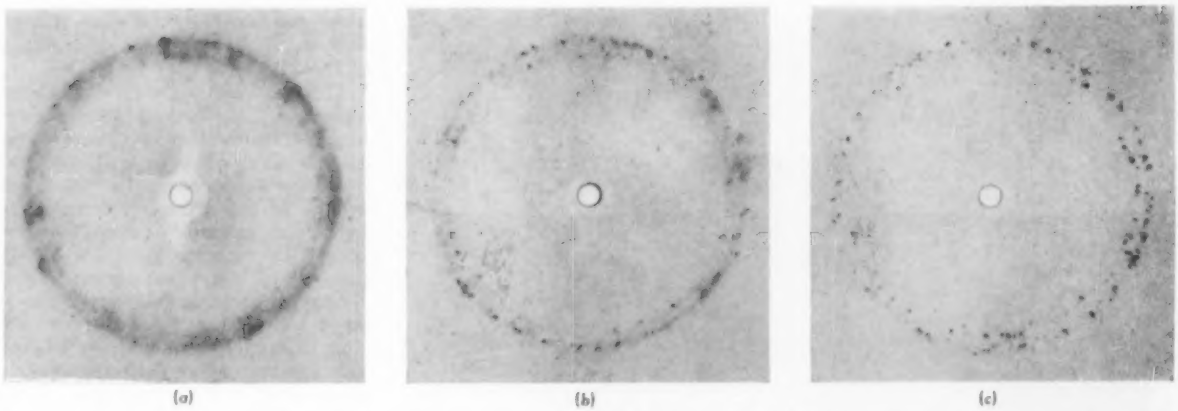
if the factor $\sqrt{2/\pi}$ is omitted. If this equation is satisfied, the elastic energy released during the crack propagation is just sufficient to cover the work $p + \alpha$ required for enlarging the walls of the crack by unit area.

Since, as just mentioned, the plastic surface work p in low-carbon steel at room temperature is probably of the order of 10^6 ergs/cm², it is about 1000 times greater than the surface energy

D. K. Felbeck is Assistant Professor of Mechanical Engineering and **E. Orowan** is George Westinghouse Professor of Mechanical Engineering; head of Materials Division, Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

This investigation was carried out in the Materials Division of the Department of Mechanical Engineering, Massachusetts Institute of Technology, for the Office of Naval Research under Contract No. N5ori-07870, D.I.C. 6949.

* The original calculations of Griffith refer to the two-dimensional case (e.g., a plate containing a crack). The "length" of the crack is then measured on the face of the plate; in the case of an edge crack, it is identical with its depth measured from the edge. The results of the calculation are approximately valid for any surface crack if the radius of curvature of the surface is large compared with the dimensions of the crack and if the width of the crack (measured along the surface) is large compared with its depth. In this case, the depth of the crack corresponds to the crack length in the two-dimensional case and is traditionally called its "length."



(a) (b) (c)

Fig. 1 (a) X-ray back reflection photograph from surface of brittle fracture of ship plate. (b) Same as (a), after removal of a layer of 0.25 mm thickness by etching. (c) Same as (a), after removal of a layer of 0.58 mm thickness by etching

which, for hard metals, is between 1000 and 2000 ergs/cm². Consequently, α can be neglected beside p, and eq 3 written as

$$\sigma \cong \sqrt{\frac{Ep}{c}} \qquad (4)$$

The initial purpose of the present investigation was to test experimentally the crack propagation condition eq 4. The most satisfactory and complete way of doing this would be to measure p independently by the X-ray method mentioned and to compare the value of σ given by eq 4 with measurements of the tensile strength of plates containing atomically sharp cracks of varying lengths c. However, the X-ray measurement of p could not be carried out with an accuracy going beyond an order-of-magnitude estimate, for the following reason. In order to establish a relationship between the diffuseness of the X-ray diffraction spots and the amount of plastic strain, a comparison chart of X-ray photographs of the same material for a series of known plastic strains has to be made. For the present purpose, strains of the order of 1 or 2% are of interest, since X-ray back reflection photographs of the surface of brittle fracture indicate plastic strains of such magnitude. However, plastic strains below the magnitude of the Lüders strain (that present in the Lüders bands before they have spread over the entire specimen) cannot be produced in macroscopic volumes, so that the required region of the comparison chart would be missing. Furthermore, the distortion in the surface of fracture is very unevenly distributed; some fragments, almost completely torn out of the surface, are severely distorted, while the grains underneath may be only slightly deformed. Owing to this circumstance, the type of spottiness seen in the X-ray photographs of the fracture surface (cf. Fig. 1, *a*) is markedly different from that obtained with a specimen distorted in tension or compression (see Fig. 2), and the comparison of the two photographs is difficult: the surface of the fracture reveals a mixture of widely different plastic strains.

After realizing this difficulty, it was decided to restrict the investigation to the measurement of fracture stresses of steel plates provided with cracks of different lengths, and the comparison of the observed relationship between σ and c with that in eq 4. If the measured σ-c curve is sufficiently well approximated by eq 4, it can be used for obtaining a value for the quantity p.

It is well known that no notch or sawcut, however sharp, can start a cleavage crack in a low-carbon steel around room temperature without extensive plastic deformation at its root. However, when the present investigation was started, it seemed that this was probably due to the fact that the root of a machined notch did not have the atomic sharpness of a cleavage crack. The plan of the experimental work, therefore, was based on the assumption that a cleavage crack, put into the specimen at a low temperature, would propagate under tension at room temperature* without more initial plastic deformation than that in a thin surface layer containing the plastic work p per unit of area (see previous discussion).

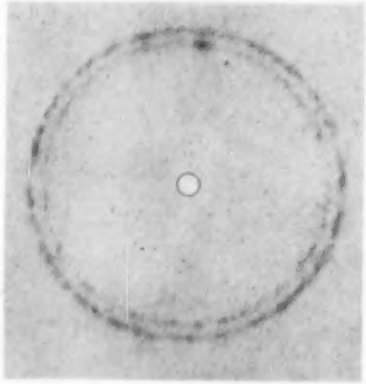


Fig. 2 X-ray back reflection photograph of annealed low-carbon steel strained 2.5% in tension

As will be seen below, one of the main results of the work was that this assumption was not fulfilled: even an atomically sharp cleavage crack could not propagate in the ship plate specimens under static tension without large plastic deformation at its root and a temporary change of the crack from the cleavage to a ductile type. Simultaneously with this work, results agreeing with it were obtained by Robertson[5].

2. Production of Specimens Containing Sharp Cracks of Given Length

The experiments were carried out on plates from the tanker *Ponaganset* which broke in two in Boston Harbor on Dec. 9, 1947. All specimens discussed in this paper were cut from a $^3/_4$-in. plate through which the crack ran when the ship broke up; its position in the hull can be identified by means of the report on the *Ponaganset* failure,[6] where it was designated by the letters "PAD."

The final size of the plate tensile specimens was about 4 in. width by 12 in. length. The width represented the upper limit that could be handled with the largest available testing machine, a Southwark-Emery hydraulic machine of 300,000 lb capacity. The specimens were provided with an initial brittle crack at the middle of one edge in the following way. First, a specimen with a side flap according to Fig. 3 was machined, and the flap provided with a notch for inserting a splitting wedge, as shown in the figure. A brittle crack was then produced by hammering the

* Provided, of course, that the transition temperature of the material was above room temperature.

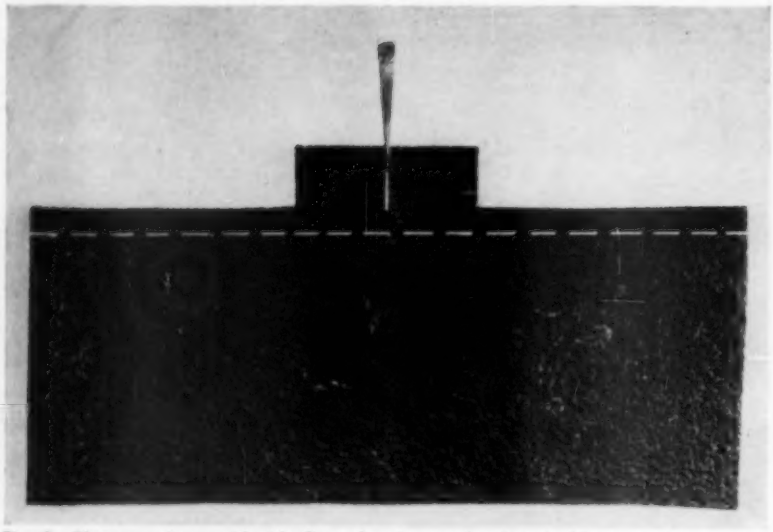


Fig. 3 Plate specimen with side flap, showing wedge inserted in saw cut

wedge into the notch after the specimen was cooled down by immersion in liquid nitrogen. The length of the crack could be controlled to a certain extent by progressive splitting with a succession of moderate blows with a hammer on the wedge. In addition, any desired length could be achieved accurately when the flap and a certain margin containing the excess length of the crack were trimmed off the plate along a line shown dotted in Fig. 3. The ends of the crack could be recognized clearly by the absence of frost in a narrow zone along the crack. Examination of the fractured specimen showed that the crack front was not straight; in the middle of the plate it was ahead of the ends of the crack visible on the surfaces of the plate.

The presence of a notch on only one side of the plate introduces a certain eccentricity. Although the effect of this can be taken into account approximately,[7] a number of experiments was carried out in which the bending moment due to the asymmetry was compensated in the way shown in Fig. 4. Two strips of 2 in. width, each provided with a crack as described above, were tacked together by welding near the ends with the cracks turned toward each other. Any bending due to the eccentricity of the individual strips would force them together and thus would be counteracted by the pressure between them. The experiments described in the following section have shown that the difference between the results obtained with the asymmetrical and the symmetrical (twin) specimens was comparatively small.

Fig. 4 Symmetrical twin specimen

3. Experiments

The load was applied to the specimens through wedge grips with roughened inner surfaces; the specimen was gripped so that its free length was about 7 in. with the crack half way between the grips, and loaded at a rate of about 1000 lb/sec. In Table 1 the measured tensile strengths are given for all specimens except those which showed obvious disqualifying irregularities of fracture appearance. In most specimens represented in Table 1, the fracture went right across the plate; in a minority, the crack stopped before the separation was complete. The corresponding data for the symmetrical specimens, cut from the same plate (PAD) as those in Table 1, are given separately in Table 2.

The relationship between breaking stress and initial crack length is shown in Fig. 5, representing the data of Table 1. The curve represents eq 4, with the value of p that minimizes the sum of the squares of the ordinate difference between the measured points and the curve; this value is $p = 4.9 \times 10^6$ ergs/cm^3. Thus the experimentally determined specific plastic energy is somewhat higher than the value derived from X-ray observations (see Section 1). Figure 6 shows the corresponding relationship for the symmetrical specimens (see Fig. 4). The value of p derived from this plot is 3.4×10^6 ergs/cm^3.

The question is whether this discrepancy is a trivial consequence of the inherent inaccuracies of measurement and evaluation, or the expression of a real difference between the plastic surface work estimated from X-ray photographs and the constant p obtained by fitting eq 4 to the data given in Tables 1 and 2. The latter possibility will be discussed in the following section.

4. Conclusions

The idea of the experiments described in the preceding section was to provide the specimen before the tensile test with a brittle crack of atomic sharpness and measure the tensile stress required for starting it to propagate. This, it was hoped, would give a direct experimental test for the crack propagation condition, eq 4.

The plots of the observed fracture stresses against the lengths of the initial cracks, shown in Figs. 5 and 6, seem at first glance to provide impressive support for eq 4: not only do the measured points lie well on curves represent-

Table 1—*Ponaganset* Plate PAD: Asymmetrical Specimens with One Edge Crack

(Room temperature tests; plate thickness: 3/4 in.; specimen length: 12 in.)

No.	Initial width, cm	Initial crack, length, cm	Fracture load, lb	Avg stress, psi	Avg stress, kg/cm^2
3	10.4	1.7	111,000	34,300	2420
4	10.0	0.9	145,000	46,800	3300
5	10.0	1.3	134,000	43,100	3040
6	10.0	2.6	87,000	28,000	1970
8	9.9	2.4	84,000	27,400	1930
9	10.0	1.0	137,500	44,400	3130
10	10.3	0.5	191,000	59,900	4220

Table 2—*Ponaganset* Plate PAD: Symmetrical Twin Specimens

(Room temperature tests; plate thickness, 3/4 in.; specimen length, 12 in).

No.	Initial width, cm	1/2 initial crack, length, cm	Fracture load, lb	Avg stress, psi	Avg stress, kg/cm^2
D-1	10.1	0.68	126,000	40,300	2840
D-2	10.1	1.2	106,000	33,800	2380
D-3	10.0	1.85	92,000	29,600	2090
D-4	10.1	2.0	91,000	29,100	2050
D-5	10.1	0.55	154,500	49,400	3480

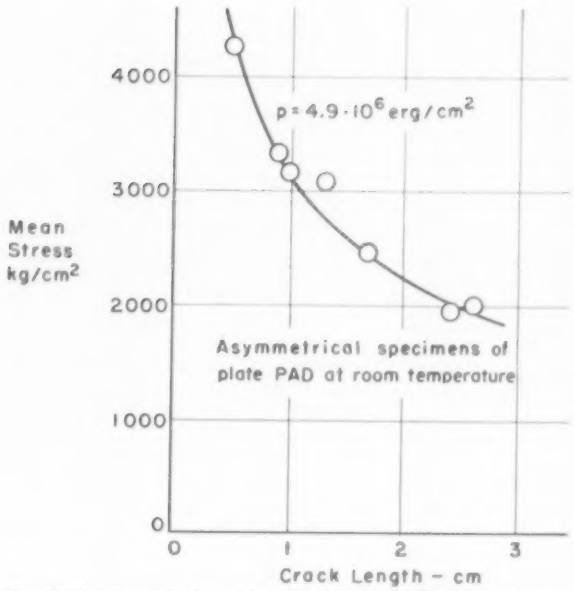


Fig. 5 Asymmetrical specimens of plate PAD at room temperature

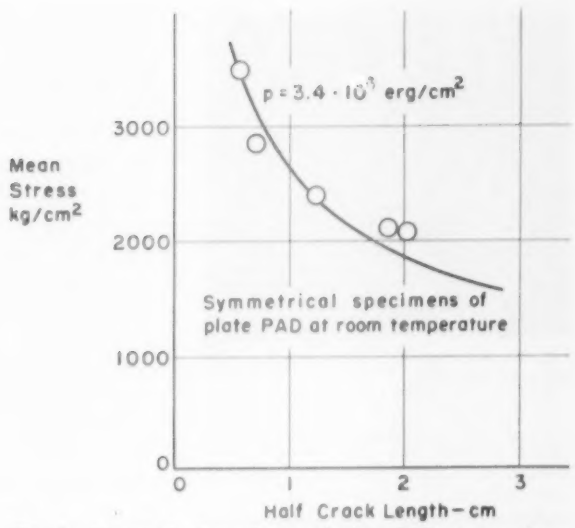


Fig. 6 Symmetrical specimens of plate PAD at room temperature

ing eq 4, but the value of p derived from them agrees in the order of magnitude with the X-ray estimate. Yet an important feature observable on the fractured specimens casts doubt not only on the significance of this agreement but also on the foundations of the classical Mesnager-Ludwik triaxial tension theory of notch brittleness. It was easy to recognize at the first visual examination of the fragments that, contrary to the expectation that underlay the program of the investigation, the initial brittle crack never continued to propagate as a brittle crack when the fracture stress was reached. First, considerable plastic deformation took place at the tip of the crack which started to propagate as a fibrous crack. After a very short run, this changed again into a brittle crack which ran across the plate at high velocity (except in the cases discussed hereafter in which the brittle crack stopped due to load relaxation and had to be restarted by raising the load). This can be seen in Fig. 7*b* where *1* is the initial brittle crack, *2* the fibrous crack and *3* the brittle crack developed from the fibrous one in the course of the test. The contraction of the thickness of the plate by the plastic deformation around the tip of the initiating crack can be recognized in the photograph. Figure 8 shows the plastic deformation at the tip of the initiating crack as it appears in view upon the face of the plate. Figure 7*c* shows the surfaces of fracture in a specimen containing a shorter initiating crack.

Occasionally, when the initial crack was long and therefore the fracture stress low, the second brittle crack did not run through the plate but stopped in it. In such cases, it could be restarted by increasing the load which, owing to the inability of the (hydraulic) testing machine to maintain the load during the rapid extension of the specimen, had dropped drastically (e.g., to one-half of the initial fracture load) by the time the crack had stopped. However, as in the first instance, the brittle crack did not propagate directly when the load was raised. Again extensive plastic deformation leading to the formation of a narrow zone of fibrous or shear fracture took place at the tip of the crack, and then the ductile crack changed to a brittle one which ran at high velocity. In a few cases, the crack stopped for a second time owing to the fall of the load, and the whole process of restarting, with the conversion into a ductile and then again into a brittle crack, could be repeated again. Figure 7*a* shows the surface of fracture of a specimen in which the crack stopped twice before fracture was complete.

Why is it that a brittle crack produced in the plate before loading cannot continue to propagate as a brittle crack when the load reaches the necessary

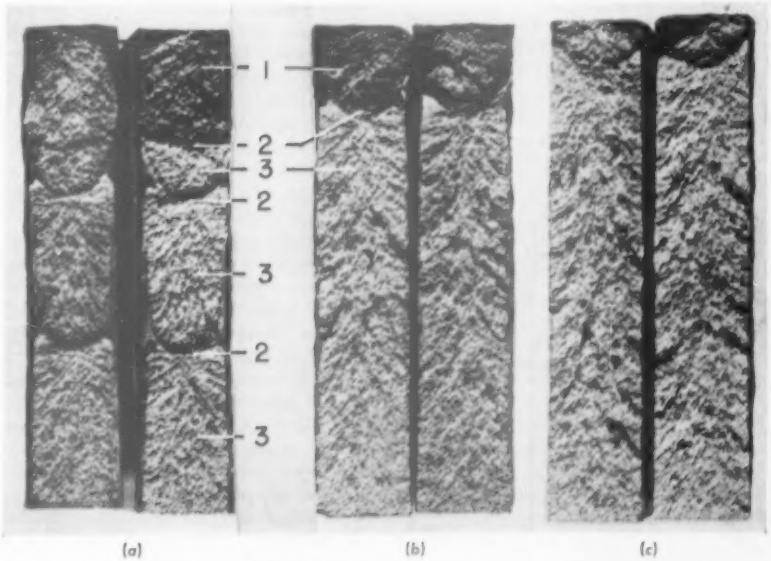


Fig. 7 Fracture surfaces showing transition from ductile to brittle crack propagation

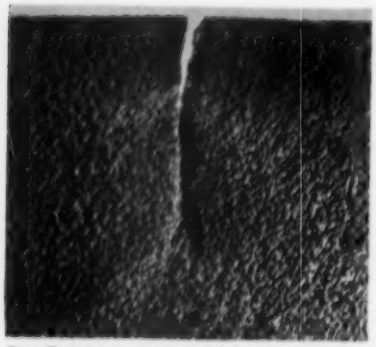


Fig. 8 Appearance of the crack at the face of the plate

value? What are the factors that compel it to change into a ductile crack with copious local plastic deformation before it can change back into a brittle crack? And, in view of this change, do the tensile tests described above have the meaning initially ascribed to them, of giving corresponding values of crack length and crack propagating stress suitable for supporting eq 4?

The only simple explanation for the inability of an atomically sharp brittle crack to continue its propagation unchanged when a tensile stress is applied is to attribute it to the absence of velocity when the propagation is resumed under a slowly applied stress. This almost unavoidable conclusion requires a drastic revision of the classical theory of notch brittleness. For the last 50 years, the brittle fracture of ductile steels was attributed, after Mesnager[8] and Ludwik,[9] to the triaxial tension arising when plastic deformation starts at the tip of a notch or a crack. Let *Y* in Fig. 9 be the ordinary uniaxial (true) stress-strain curve of the material in tension; fracture of the ductile (fibrous or shear) type occurs at the point *F*. Curve *B* represents the brittle strength (brittle fracture stress); since it lies above the yield stress-strain curve *OF*,

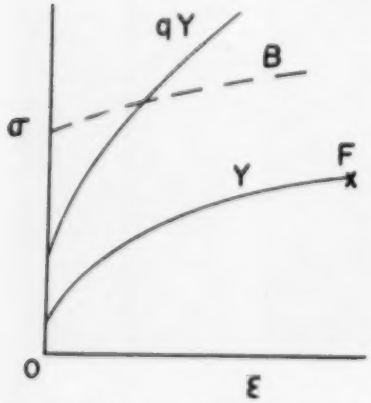


Fig. 9 To the triaxial tension theory of brittle fracture

no brittle fracture can occur in the ordinary tensile test. However, brittle fracture is possible if the maximum tensile stress required for yielding is raised above the values given by the curve *OF*. This can be done by:

1. lowering the temperature: ferrous materials become brittle at a sufficiently low temperature;
2. increasing the rate of straining: ferrous materials have an abnormally high velocity-dependence of the yield stress-strain curve;
3. superposing a hydrostatic tension, e.g., by plastic constraint in a specimen containing a crack or a notch.

The classical theory of notch brittleness saw its main cause in the triaxial tension produced by notch constraint. The way in which this acts can be described very simply, without any reference to triaxiality, in the following manner. In a specimen containing a notch or a crack, plastic deformation starts in the region of stress concentration at the tip of the notch. However, this region is embedded in less highly stressed surroundings that have not reached the point of yielding at the same time; consequently, the region of stress concentration cannot yield freely before the maximum tensile stress in it has increased to the magnitude required for overcoming both the constraint of the surroundings and its own resistance to plastic deformation. It can be shown that this effect can raise the maximum tensile stress reached at yielding up to about three times the value of the uniaxial tensile yield stress if the notch is very deep and sharp. In the presence of a notch, therefore, the maximum principal tensile stress plotted against the plastic strain will be represented by a curve like that denoted by *qY* in Fig. 9, and this may intersect the curve *B* of the brittle strength before the plastic deformation could reach the value necessary for ductile fracture to occur. In this case, the specimen undergoes brittle fracture.

As mentioned above, the Mesnager-Ludwik theory attributed brittle fracture in commonly ductile steels primarily to the development of a triaxial tension during plastic yielding at the tip of a notch or a crack. Such a triaxiality requires the occurrence of plastic deformation; without this, only a small effect due to elastic constraint can be present. How much plastic deformation is necessary for the development of full plastic constraint has never been calculated; it was implicitly assumed that deformation extending over a very small (perhaps microscopically small) region around the tip of the crack would be sufficient. The observations described above indicate strongly that this expectation was mistaken: quite extensive deformation around the tip of the crack is required, either because the region of highest tensile stress has to reach a certain critical size before cleavage can occur, or because the effect of plastic constraint in raising the tensile stress has to be complemented by strain hardening.[10] Once this is assumed, the explanation of the phenomenon shown in Fig. 7 presents no difficulty. If a fracture appears quite brittle, it cannot involve plastic deformation sufficient for the development of considerable plastic constraint and strain hardening: brittle fracture must then be due to the raising of the yield stress to the level of the brittle strength by the velocity effect. If a crack travels fast, any plastic deformation that may occur at its tip involves an extremely high strain rate and so requires a strongly increased yield stress. With most metals, even the highest velocities cannot increase the yield stress more than 20 or 30%; according to several investigators,[11, 12] however, the yield stress (possibly only the upper yield point) of low-carbon steels increases by a factor of 2 or 3 at high rates of deformation. This would be quite sufficient to replace fully the highest possible plastic constraint effect. But if the brittleness is due mainly to a velocity effect, the crack put initially into the specimen cannot start propagating in the typical brittle manner under static load because it has no velocity. Consequently, local plastic deformation sets in, and plastic constraint develops until the triaxiality of tension is high enough to change the initial fibrous crack propagation into a brittle one. Once this has taken place, the crack accelerates rapidly and further plastic deformation becomes unnecessary because the velocity effect takes over from the plastic constraint effect the task of raising the maximum tensile stress to the level of the brittle fracture stress.

Figure 7*a* shows clearly that, at not too low temperatures, the velocity effect alone may not be sufficient for raising the yield tension to the value of the brittle strength. At the free surface of a plate, no triaxiality can exist: consequently, some plastic deformation with ductile (shear) fracture must occur here if the velocity effect alone is insufficient, and the well-known phenomenon of the "shear lip" arises. The plastic deformation produces a slight but sharp constriction running in the form of a shallow and narrow rounded groove along the line of fracture on the surfaces of the plate. This is the same phenomenon as the necking of a tensile specimen, and it is likewise accompanied by the development of transverse tensions in the interior which, added to the velocity effect, lead to brittle fracture everywhere except at the shear lip where,

owing to proximity of the free surface, the degree of triaxiality becomes too low. Thus, the width of the shear lips gives a measure of how much the velocity effect falls short of being able to produce brittle fracture alone. This is impressively seen in Fig. 7*a*. When the brittle fracture starts at the fibrous "nail" *2*, it soon attains high velocity, and the shear lip is quite narrow. However, as it progresses, the load drops because the testing machine cannot follow the fast expansion of the specimen, and the velocity of the crack decreases. With this, more and more of the velocity-effect upon the yield stress has to be replaced by a plastic constraint effect, and the width of the shear lip increases until finally the two shear lips join up to a parabolic arc. At this point, the crack stops, possibly after it has produced a very narrow margin of a ductile crack, a second fibrous "nail."

This picture of brittle fracture changes the classical concept in which triaxiality was the fundamental effect. It seems now that triaxiality alone cannot produce really brittle fracture except at low temperatures because, before it can lead to cleavage, it requires considerable plastic deformation. Whenever a fracture is truly brittle (i.e., of extremely low energy consumption), this must be due mainly to the velocity effect, unless the temperature is so low that the relatively small elastic constraint effect is sufficient. Triaxiality may be important in starting off brittle crack propagation, as seen in the above experiments; it is doubtful, however, whether it is indispensable for this purpose. Many service fractures do not reveal any visible trace of plastic deformation at their starting point. This effect could be reproduced in laboratory experiments by using plate specimens containing a weld.[13, 14] It seems, therefore, that heating or cooling under stress creates a condition in which cleavage can start under static load without preceding large deformations.

The observation that the initiating cleavage crack never spread under the applied stress but always changed first into a ductile crack before reverting to the cleavage type raises the question whether the use of the crack propagation condition eq 4, as it was done in Section 3, can still be justified. It is easy to see that the incisive change in the theoretical picture of notch brittleness to which the above experiments have led has clarified the significance of eq 4. The conditions of *brittle* cleavage now include a high velocity of the crack, and this can be reached only if the energy to be fed into it (in the form of the surface work p) can be obtained from the elastic energy released during its propagation. Otherwise, very high velocities of load application would be necessary. If the tensile stress σ is not below the value demanded by eq 4, the work needed for enlarging the crack can be obtained from the released elastic energy. Equation 4, therefore, is the condition for the high velocity of crack propagation required for brittle cleavage to be reached under static or nearly static loading. From this, it does not follow that the fracture stresses observed in the present experiments must have been those given by eq 4: they must have been higher than this value. In the present experiments, brittle fracture could not occur unless:

(*a*) the plastic deformation needed for starting cleavage could take place at the tip of the initial crack; and

(*b*) the condition for crack acceleration eq 4 was fulfilled.

It can be shown[15] that the Griffith-type equation (eq 4) is equivalent to a stress concentration condition. If it is satisfied, the applied tension is capable of producing plastic deformation at the tip of the crack in a region the radius of which is equal to the thickness of the cold-worked layer in which the plastic surface work p is done. The thickness of this layer, according to the X-ray evidence mentioned above, is of the order of 0.3 or 0.5 mm; since the tensile stress needed for producing yielding in a region of this size is lower than that required for yielding in the much larger area that has to be deformed before the crack can start to propagate, the stress required for satisfying condition (*a*) is higher than that demanded by (*b*). Consequently, the fracture stress is the starting, not the accelerating, stress.

That the observed fracture stresses are approximately inversely proportional to the square root of the crack length is not surprising. According to a theorem due to Neuber,[7, 16] the mean tensile stress σ needed to produce plastic yielding at the level of the (constrained) yield stress σ_m in a region of radius r at the tip of a crack of length c is

$$\sigma \approx \sigma_m \cdot 1/2\sqrt{r/c} \qquad (5)$$

If, therefore, the size of the plastically deformed region required for starting cleavage is fairly independent of the crack length, the fracture stress should be inversely proportional to $\sqrt{c}$.

References

1. Griffith, A. A., *Phil. Trans. Roy. Soc.*, **A221**, 163 (1920).
2. Griffith, A. A., *First Internat. Congr. Appl. Mech.*, Delft, p. 55 (1924).
3. Orowan, E., *Repts. on Progress in Physics*, **12**, 185 (1949).
4. Orowan, E., *Trans. Inst. Eng. and Shipbuild., Scotland*, **89** (Paper No. 1063), 165 (1945).
5. Robertson, T. S., *Engineering*, **172**, 445 (Oct. 5, 1951).
6. McCutcheon, E. M., Pittiglio, C. L., and Raring, R. H., THE WELDING JOURNAL, **29** (4), Research Suppl., 184-s to 194-s (1950).
7. Neuber, H., *Kerbspannungslehre*, Berlin (1937).
8. Mesnager, A., Internat. Assn. for Testing Materials, Brussels Congress 1906, Rapport non-offic., No. A 6f, pp. 1–16.
9. Ludwik, P., and Scheu, R., *Stahl u. Eisen*, **43**, 999 (1923).
10. Wells, A. A., *Welding Research (London)*, **6**, 68r (August 1952).
11. Clark, D. S., and Dätwyler, G., *Proc. ASTM*, **38**, 98 (1938).
12. Taylor, G. I., *J. Inst. Civil Eng.*, **26**, 486 (October 1946).
13. Week, R., *Welding Research (London)*, **6**, 70r (August 1952).
14. Greene, T. W., THE WELDING JOURNAL, **14** (5), Research Suppl., 193-s to 204-s (1949).
15. Orowan, E., "Energy Criteria of Fracture," THE WELDING JOURNAL. In press.
16. Orowan, E., in *Fatigue and Fracture of Metals* (Symposium held at MIT June 1950), Cambridge, Mass., New York and London, p. 136 (1952).

EFFECTS OF RESIDUAL STRESSES IN WELDED STRUCTURES

DISCUSSION BY A. W. HUBER AND L. S. BEEDLE

It is the purpose of this discussion to comment on the influence of residual stresses on members loaded in compression. The author refers only briefly to the influence of residual stresses on instability. Recently much new information has been added to the subject.[1–4] Theory and tests on both axially and eccentrically loaded rolled steel columns of ordinary wide-flange shape clearly indicate a pronounced influence of residual stress upon the ultimate strength.

It is true that there is no influence of residual stresses on "slender" axially loaded steel columns in the Euler buckling range provided the sum of the applied stress and residual stress does not exceed the proportional limit. Therefore it is more appropriate to speak of inelastic instability or elastic-plastic instability. The bending stiffness, EI, in

A. W. Huber is Research Instructor and **L. S. Beedle** is Assistant Director, Fritz Engineering Laboratory, Lehigh University, Bethlehem, Pa.

Paper by G. M. Boyd was published in the May 1955 WELDING JOURNAL Research Suppl., pp. 216-s to 222-s.

the Euler buckling formula is modified to the bending stiffness, EI_n, of the unyielded part of the cross section (see References 2 and 4).

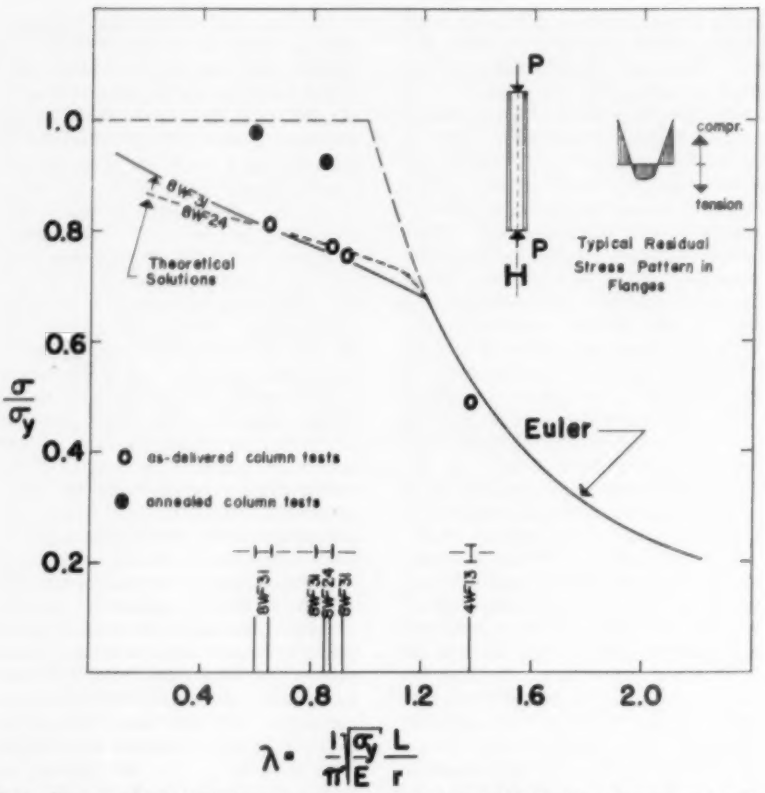
The influence of residual stress in the case of axially loaded steel columns is clearly demonstrated in the accompanying figure. The results of annealed and as-delivered columns, free to bend in the weak direction, are compared on a nondimensional basis. Theoretical solutions are also shown which agree very well with tests. The residual stresses, in this case, are those formed due to cooling after rolling. The solid test points represent members which were annealed and thus nearly free from all residuals. As a result they are closer to the horizontal dashed line that represents the strength of an ideal column free from residual stresses.

Residual tension stresses in welds can amount to as high a value as the yield point but are rather localized in the neighborhood of the weld (see author's Fig. 1). It would be expected that the compressive stresses, generally, would be low in magnitude. Thus, in the case of welded columns, built up from plates, a smaller reduction in column strength is possible.

The author refers to the tests made at the University of Illinois[5] on welded built-up columns. These columns had an effective slenderness ratio, KL/r, between 35 and 41 since they were tested in flat-ended conditions ($K \doteq 0.55$). Actually they were short and *not* slender columns. As has been shown[4] the effect of residual stresses is greatest for intermediate columns of an effective slenderness ratio between 50 and 110.

Residual stresses were undoubtedly present in the material used to make the built-up columns in the University of Illinois tests. Further, tests of the unreinforced columns inherently included the effects of residual stresses. The addition of cover plates by welding probably did not result in an unfavorable change in residual stress distribution as can be deduced from the remarks made earlier. This and the low effective slenderness of the columns seem to be the reason that the reinforcement plates appeared to be 100% effective in increasing the load-carrying capacity over unreinforced columns. However, it would be erroneous to conclude from these tests that generally residual stresses have no detrimental effect upon column strength.

As was shown in Reference 4, even though the presence of residual stresses reduces column strength, this does not mean that structures are unsafe that were designed according to formulas neglecting the effect of residuals. Current specifications are conservative, in this regard, since they are based, in part, on tests. Of course, the test members contained residual stresses.



The influence of residual stress on column strength as indicated by theory and tests

Through the sponsorship of Column Research Council, Pennsylvania Department of Highways, Bureau of Public Roads, and National Science Foundation, work is continuing at Lehigh University on a project to determine the basic compressive strength of steel columns, including the effect of residual stresses. The studies include not only rolled shapes but also columns built up of plates and shapes. One of the eventual objectives is to suggest a column strength formula that will include the effect of residual stresses.

References

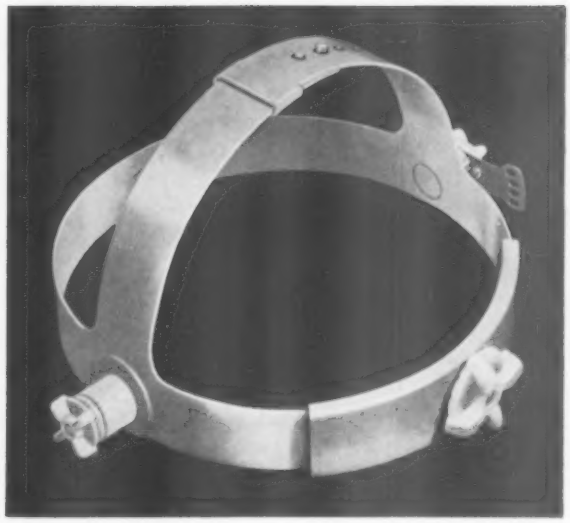
1. Osgood, W. R., "The Effect of Residual Stress on Column Strength," Proc. First Nat. Congress of Appl. Mech., June 1951.
2. Yang, C. H., Beedle, L. S., and Johnston, B. G., "Residual Stress and the Yield Strength of Steel Beams," THE WELDING JOURNAL, 31 (4), Research Suppl., 205-s (1952).
3. Ketter, R. L., Kaminsky, E. L., and Beedle, L. S., "Plastic Deformation of Wide-Flange Beam Columns," Proc. Sep. No. 330, ASCE, Vol. 79, 1953.
4. Huber, A. W., and Beedle, L. S., "Residual Stress and the Compressive Strength of Steel," THE WELDING JOURNAL, 33 (12), Research Suppl., 589-s (1954).
5. Wilson, W. M., and Brown, R. L., *The Effect of Residual Longitudinal Stresses Upon the Load-Carrying Capacity of Steel Columns*, University of Illinois Engineering Experiment Station, Bulletin No. 280, November 1935.

AUTHOR'S REPLY

The discussers are sincerely thanked for their valuable contribution, which fills a serious gap in the knowledge available at the time the paper was written. They are also thanked for the correction in regard to the slenderness ratios of the columns tested at Illinois.

The data furnished in their diagram give little information on the effects of residual stresses in the elastic part of the column curve, i.e., where the determining criterion is of the Euler form. Such information will no doubt emerge from the further work referred to, and the results of this are awaited with interest.

The contribution does not affect the conclusions of the paper, although in view of the data given it might be more correct to substitute "compressive" for "elastic" in conclusion No. 1.



NEW All Nylon Adjust-O-Lok Headgear

Nylon, lightweight and non-conductive, lends its superior, long wearing strength to every part of this completely redesigned arc welding helmet headgear.

The large, easy to handle winged knob and the gear, both of Nylon, engage a Nylon headband to give fine adjustment to head size while helmet is worn. Headband is molded in one piece with a cross strap, *now also adjustable*, over the top of the head. The headband adjustment is entirely enclosed in a Geon sleeve, smooth fitting against the head. A cork-lined sweatband is available at extra cost.

Jackson Leads Way with Better Helmets

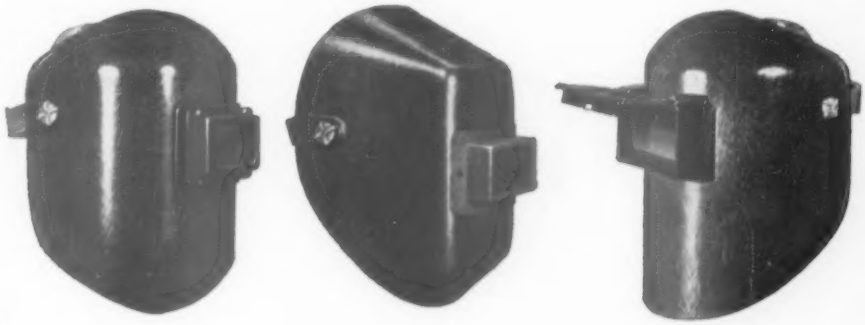
NEW Nylon Friction Pivots

All pivot parts are Nylon, except the entirely enclosed spring, so no current can pass through to the wearer's head. New winged nuts provide easier hand adjustment from the outside without taking the helmet off. A stop, located inside of the helmet shell, is attached to one of the Nylon pivots to halt the helmet's down movement, and is quickly adjusted to the exact position you may require.

NEW Straight Front Helmets with Fiber Glass Shells

To those who prefer helmets of this popular shape, JACKSON now offers a line of helmets of the same quality as its curved and narrow shell styles, with the same new features. Made of fiber glass, strong, smooth, easy to clean, resistant to heat and moisture, *they last.*

For the Best in Arc Welding Helmets Jackson Offers You 3 × 3 × 2 = 18 Models to Choose from



YOUR CHOICE OF:

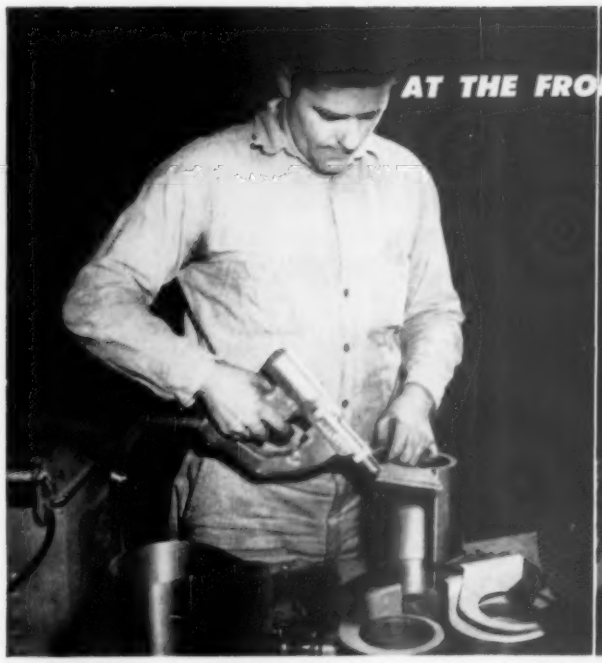
3 HELMET SHELLS...	CURVED SHELL	NARROW SHELL	STRAIGHT SHELL
3 LENS HOLDERS...	PLASTIC FIXED FRONT	METAL FIXED FRONT	PLASTIC LIFT FRONT
2 HEADGEARS...	THE NEW ALL-NYLON ADJUST-O-LOK — OR THE ECONOMY HEADGEAR No. 62		

All Lens Holders and Headgears are Interchangeable

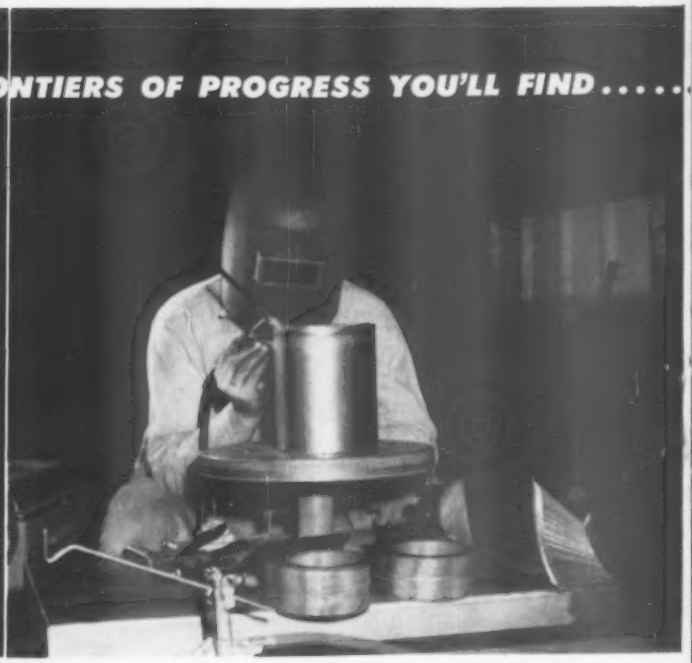
Made by the World's Largest Manufacturer of Arc Welding Electrode Holders, Ground Clamps and Cable Fittings, Sold World-Wide through Distributors and Dealers.

JACKSON
PRODUCTS, INC.
WARREN · MICHIGAN

AT THE FRONTIERS OF PROGRESS YOU'LL FIND.....



STEP 1. Using an Aircospot gun, (which takes one second to make a strong, sound spot weld), the Falstrom operator tack-welds flange on a metal cover. An average of 10 tacks are needed. The metal is 16 gauge mild steel.



STEP 2. Mounting the tack-welded unit on a turntable, the same operator exchanges the Aircospot gun for an H8-B Heliweld holder. The Airco Heliweld process joins the circumferential seam at a speed of 16 inches per minute.

Falstrom Company
...eliminates jigs and back-up plates with AIRCOSPOT
...speeds seam-welding 75% with HELIWELDING!

It used to take 17 minutes to tack and weld a complete metal cover at the Falstrom Company, Passaic, N. J. Now, with a combination of Aircospot and Airco Heliwelding, this operation has been reduced to a fraction of the time.

Previous methods of tack-welding required the use of jigs and fixtures — a procedure that hampered the operator and slowed production. Aircospot, however, tack-welds from just one side of the metal. It eliminates jigs and back-up plates, completely streamlining the work flow. At the same time, by using Heliwelding instead of oxyacetylene welding, Falstrom was able to reduce welding time 75%. This faster method of welding thin sections of metal provided further economies as the end product required less finishing and grinding.

One, or both, of these Airco inert-gas shielded arc welding processes can provide similar savings in your particular operation. Contact your local Airco Sales Representative or Authorized Airco Dealer for an on-the-spot demonstration in your plant — or — write Airco direct for complete information. Request Aircospot Catalog #2315, Heliwelding Catalog #2300.

AIRCO®

AIR REDUCTION

60 East 42nd Street • New York 17, N. Y.

Divisions of Air Reduction Company, Incorporated, with offices and dealers in most principal cities

Air Reduction Sales Company
Air Reduction Pacific Company

Represented internationally by
Airco Company International

Foreign Subsidiaries:
Air Reduction Canada Limited
Cuban Air Products Corporation

Products of the divisions of Air Reduction Company, Incorporated, include: **AIRCO** — industrial gases, welding and cutting equipment, and acetylenic chemicals • **PURECO** — carbon dioxide, liquid-solid ("DRY-ICE") • **OHIO** — medical gases and hospital equipment • **NATIONAL CARBIDE** — pipeline acetylene and calcium carbide • **COLTON** — polyvinyl-acetates, — alcohols, and other synthetic resins.